ENERGY CONSERVATION AND WIND ENERGY FEASIBILITY
FOR KITKATLA, B.C.

ENERGY CONSERVATION AND WIND ENERGY FEASIBILITY STUDY FOR KITKATLA, B.C.

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SUMMARY

This report documents a study of energy supply and use for the community of Kitkatla, a stable community of approximately 500 people on the north coast of B.C. The community of Kitkatla presently spends $352,800 per year on various fuel supplies for heating, electrical production, fishing and community and school buildings. Figure 1 shows energy supplies and energy flows for Kitkatla. The two major components of the study were an assessment of the potential for energy conservation, and a detailed assessment of the wind power potential to reduce oil use.

Analyses of energy saving options available to the community are detailed in the report. Briefly, these are:

- energy management techniques costing little or nothing to implement;
- cost-effective reinsulation and building improvements to reduce energy use. A detailed table of measures showing costs and savings was developed and is presented in Section 4.3;
- water heating and heating system improvements; and
- electrical generation by load matching and generator sequencing.

Figure 2 is an energy savings options chart listing various approaches for reducing or replacing fuel oil in Kitkatla.

The energy saving priorities are to reduce oil use - for heat and for electricity. As in other diesel generator communities, it is important to recognize that the real cost of electricity is not paid by the local residents, hence the incentive to conserve is not as great as it should be.

Alternative energy resources for Kitkatla were evaluated: wind, wood, solar, small hydro and others. A detailed wind energy resource assessment was made involving a wind speed measurement program and a comparison with four nearby wind stations - Bonilla, Lawyer, Lucy and Triple Islands. Long term wind availability was determined and used in evaluating four

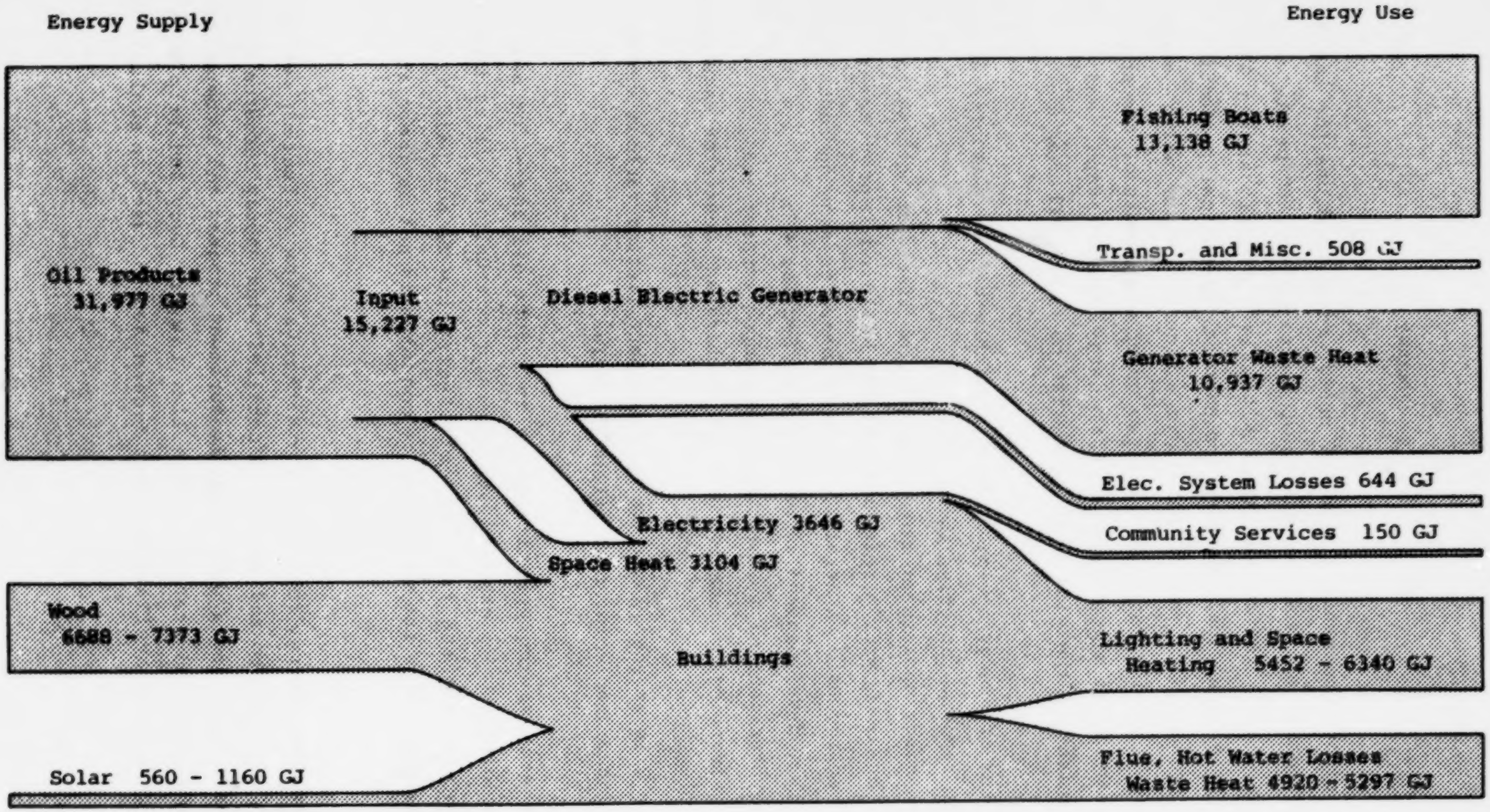
Energy Supply
Energy Use
Oil Products
31,977 GJ
Input
15,227 GJ
Diesel Electric Generator
Fishing Boats
13,138 GJ
Transp. and Misc. 508 GJ
Generator Waste Heat
10,937 GJ
Elec. System Losses 644 GJ
Electricity 3646 GJ
Space Heat 3104 GJ
Community Services 150 GJ
Wood
6688 - 7373 GJ
Buildings
Lighting and Space
Heating 5452 - 6340 GJ
Solar 560 - 1160 GJ
Flue, Hot Water Losses
Waste Heat 4920 - 5297 GJ

Figure 1. Energy Supplies and Energy Flows for Kitkatla Community

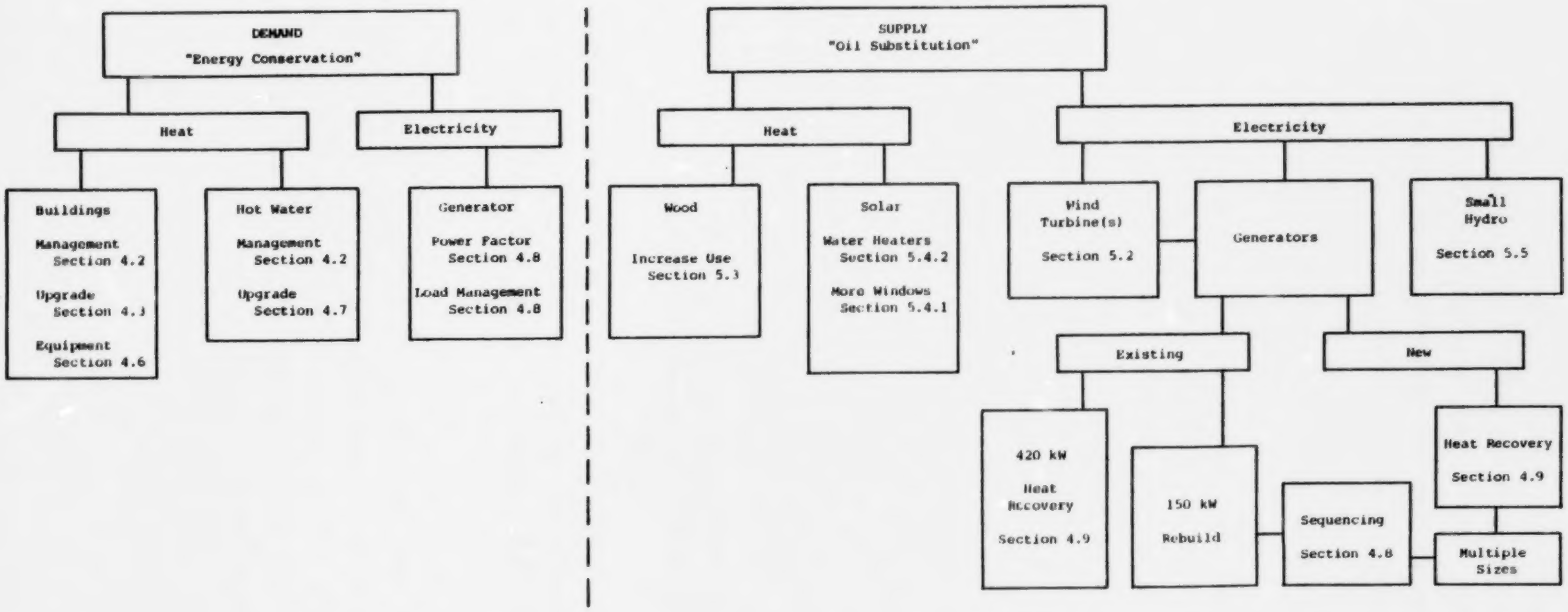
DEMAND
"Energy Conservation"
Heat
Electricity
Buildings
Management Section 4.2
Upgrade Section 4.3
Equipment Section 4.6
Hot Water
Management Section 4.2
Upgrade Section 4.7
Generator
Power Factor Section 4.8
Load Management Section 4.8
SUPPLY
"Oil Substitution"
Heat
Electricity
Wood
Increase Use Section 5.3
Solar
Water Heaters Section 5.4.2
More Windows Section 5.4.1
Wind Turbine(s)
Section 5.2
Generators
Small Hydro
Section 5.5
Existing
New
420 kW
Heat Recovery
Section 4.9
150 kW
Rebuild
Sequencing
Section 4.8
Heat Recovery
Section 4.9
Multiple Sizes

Figure 2. Energy Savings Options Chart for Kitkatla Community with Report Section Number References.

types of wind turbines. The best option could produce electricity at $ .14/kWh, and would be cost-effective in displacing fuel from the diesel generator. Total cost was estimated to be $170,000, saving $30,000 worth of fuel annually. Detailed feasibility and system design are recommended. Additional wind speed monitoring on a lower ridge closer to the village is also recommended to optimize wind potential and installed system costs.

Wood presently contributes between 25% and 27% of the non-commercial energy requirements. Wood has displaced 74% to 81% of potential oil use for residential heating purposes. Solar presently contributes between 8% and 16% of space heating. At present solar system prices, solar domestic water heaters are not cost-effective for homeowners because they pay less than the real cost of electricity. It is cost-competitive (15 to 20 year payback) for the utility or diesel operator to invest in solar water heaters to displace electricity used to heat water.

A preliminary analysis showed that a small hydro site on a nearby island may be able to replace present diesel generation needs cost-competitively. Projected capital costs were $1.65 million, saving $160,000 worth of fuel per year. Further assessment work should be undertaken in this regard. An inventory of other alternative resources was made; none were perceived to be both technically and economically feasible in the near future.

In conclusion, substantial fuel savings are possible. Energy conservation measures are available in conjunction with financial assistance for home reinsulation. For renewable resources, two options emerged to reduce generator fuel use:

- a lower-cost lower-savings wind energy project - with an estimated cost of $170,000 providing fuel savings of $30,000 per year; and
- a greater-cost greater-savings small hydro system - with a preliminary estimated cost of $1.65 million providing fuel savings of $160,000 per year.

ETUDE DES POSSIBILITES D'ECONOMIES D'ENERGIE ET D'UTILISATION DE L'ENERGIE DU VENT A KITKATLA (C.-B.)

Résumé

Ce rapport rend compte d'une étude de la disponibilité et de l'utilisation de l'énergie dans la localité de Kitkatla, qui compte une population stable d'environ 500 personnes et qui est située sur la côte nord de la Colombie-Britannique. La localité de Kitkatla dépense actuellement 352 000 $ par année en divers combustibles qui servent au chauffage, à la production d'électricité, à la pêche et aux établissements collectifs et scolaires. L'étude consistait d'une part à évaluer les possibilités d'économies d'énergie et d'autre part à analyser de façon approfondie les possibilités d'utilisation de l'énergie éolienne pour réduire la consommation de mazout.

Les diverses possibilités d'économies d'énergie qui s'offrent à la collectivité sont analysées en détails dans le rapport. Les voici énumérées brièvement:

- techniques de gestion énergétique dont la mise en oeuvre ne coûte rien ou presque rien;
- réfection de l'isolation et autres améliorations des bâtiments qui se justifient sur un plan économique, afin de réduire la consommation d'énergie (les auteurs ont construit un tableau détaillé des mesures à prendre, qui indique les coûts de ces mesures et les économies d'énergie qu'elles rendent possible);
- amélioration des systèmes de chauffage de l'eau et des locaux; et
- production d'électricité par mise en équilibre de la demande et de la production et synchronisation des groupes générateurs.

Les auteurs ont évalué diverses ressources énergétiques qui s'offrent à la localité de Kitkatla: vent, bois, énergie solaire, électricité de mini-centrales et autres. Ils ont procédé à une évaluation approfondie des ressources en énergie éolienne, en procédant à des mesures de la vitesse du vent et en comparant les résultats obtenus aux stations avoisinantes des îles Bonilla, Lawyer, Lucy et Triple. Ils ont calculé la disponibilité à long terme du vent et se sont servis des résultats pour évaluer quatre types d'éoliennes. Dans le meilleur des cas, il serait possible de produire de l'électricité au coût de 0,14 $/kWh, ce qui reviendrait moins cher que le combustible utilisé dans les centrales au diesel. Les auteurs ont estimé que cette solution coûterait 170 000 $ et qu'elle ferait économiser 30 000 $ de combustible par année. Ils recommandent des études de faisabilité détaillées ainsi que des études de systèmes. Ils recommandent aussi de procéder à d'autres mesures de la vitesse du vent à une élévation moindre, plus près du village, en vue d'optimiser le potentiel éolien et les coûts des systèmes après installation.

Actuellement, le bois comble entre 25 et 27 % des besoins énergétiques non commerciaux. Il écarte ainsi entre 74 % et 81 % du mazout qui pourrait être utilisé pour le chauffage résidentiel. L'énergie solaire, quant à elle, fournit entre 8 et 16 % de la chaleur nécessaire au chauffage des locaux. Aux prix du marché actuels, les chauffe-eau solaires domestiques ne sont pas rentables dans le secteur résidentiel. Cependant, il est payant pour l'entreprise de service public et l'exploitant d'une centrale au diesel d'investir dans des chauffe-eau solaires pour remplacer l'électricité servant au chauffage de l'eau.

Selon une analyse préliminaire, une mini-centrale hydroélectrique construite sur une île avoisinante pourrait satisfaire, de façon concurrentielle, des besoins actuellement comblés par des centrales au diesel. Le coût d'investissement d'une telle centrale est estimé à 1,65 million de dollars et ferait économiser 160 000 $ de combustible par année. Il y aurait lieu de procéder à d'autres évaluations à cet égard. D'autres ressources ont également été recensées; aucune n'apparaît techniquement ou économiquement possible à exploiter dans un proche avenir.

En conclusion, des économies de combustible appréciables sont possibles. Des mesures d'économies d'énergie peuvent être mises en oeuvre parallèlement à la réfection de l'isolation que les propriétaires exécutent à la faveur d'une aide financière du gouvernement. En ce qui concerne les ressources renouvelables, on a retenu deux solutions pour réduire la consommation de combustible dans les centrales thermiques:

- une éolienne, qui coûte 170 000 $ et qui fait économiser 30 000 $ de combustible par année; et
- une mini-centrale hydroélectrique, qui coûte 1,65 million de dollars et qui fait économiser 160 000 $ de combustible par année.

Cette étude a été exécutée par la firme SAR Engineering de Vancouver, à la demande du Conseil des bandes indiennes de Kitkatla, dans le cadre du Programme de démonstration dans les collectivités éloignées du ministère de l'Energie, des Mines et des Ressources du Canada. Des services et de l'information ont également été fournis par le ministère fédéral des Affaires indiennes et du Nord et par le Conseil national de recherches du Canada.

1.0 INTRODUCTION

The Remote Community Demonstration Program was implemented by Energy, Mines and Resources Canada to assist communities which rely upon petroleum based energy resources to reduce their dependence on oil and the associated financial commitments.

1.1 Objectives

The purpose of this study was to assess both the energy supply and use for Kitkatla and to evaluate the potential for energy conservation and wind energy to reduce oil dependence in Kitkatla. Specific objectives were to:

- analyze the existing and potential energy supplies for the community of Kitkatla;
- assess the technical and economic potential for energy conservation;
- measure short term wind speeds at Kitkatla, compare these with nearby wind station data and to evaluate the technical and economic feasibility of utilizing wind energy to provide electricity and reduce diesel fuel use;
- determine the potential for solar energy applications;
- perform a preliminary analysis of the likely potential for small scale hydro systems to contribute to Kitkatla electrical needs; and,
- review additional potential energy sources and applicability to Kitkatla.

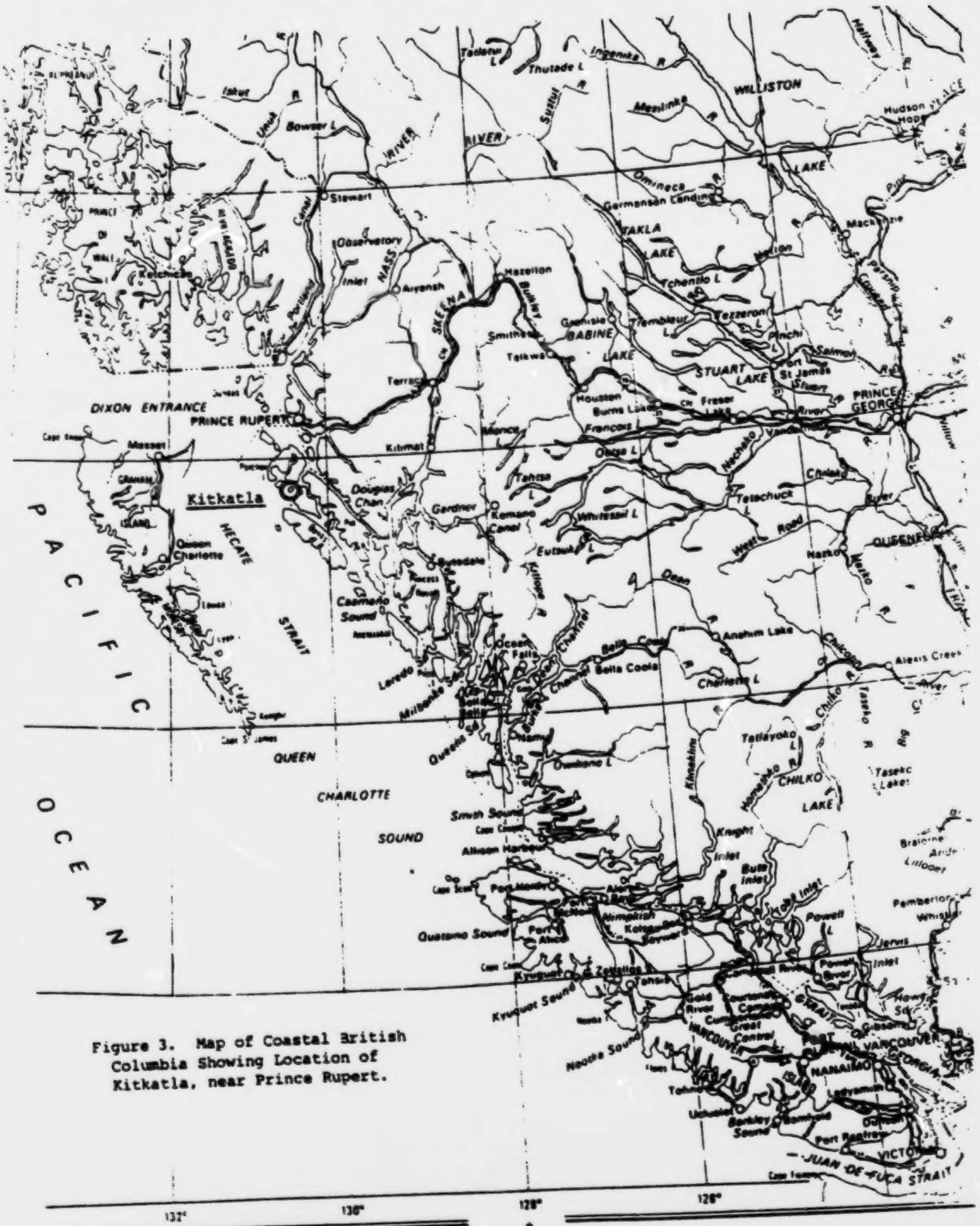
PACIFIC OCEAN
DIXON ENTRANCE
PRINCE RUPERT
Kitkatla
HECATE STRAIT
QUEEN CHARLOTTE SOUND
Masset
Queen Charlotte
Stewart
Observatory Inlet
Aiyansh
NASS
SKEENA
Hazelton
Smithers
Terrace
Kitimat
Douglas Chan.
Gardner Canal
Kemano
Bella Coola
Ocean Falls
Milbanke Sd.
Smith Sound
Allison Harbour
Port Hardy
Quatsino Sound
Port Alice
Kyuquot Sound
Nootka Sound
Tofino
Ucluelet
Barkley Sound
Port Renfrew
JUAN DE FUCA STRAIT
VICTORIA
NANAIMO
VANCOUVER
STRAIT OF GEORGIA
Powell River
Knight Inlet
Bute Inlet
CHILKO LAKE
Tatlayoko L
Anahim Lake
Alexis Creek
Charlotte L
Tetachuck L
Whitesail L
Eutsuk L
Ootsa L
Francois L
Burns Lake
Houston
Fraser Lake
PRINCE GEORGE
STUART LAKE
Fort St James
BABINE LAKE
TAKLA LAKE
Germansen Landing
Omineca R
WILLISTON LAKE
Mesilinka R
Ingenika R
Thutade L
Bowser L
Iskut R
Hudson Hope
Mackenzie
Tchentlo L
Trembleur L
Tezzeron L
Pinchi
QUESNEL
Nazko
Chilcotin R
Taseko R
Bralorne
Lillooet
Pemberton
Whistler
Jervis Inlet
Gibsons
Ladysmith
Duncan
Gold River
Courtenay
Comox
Campbell River
Zeballos
Tahsis
Alert Bay
Port McNeill
Nimpkish
Kitimat
Cape Scott
Cape St James
132°
130°
128°
126°

Figure 3. Map of Coastal British Columbia Showing Location of Kitkatla, near Prince Rupert.

1.2 Background

Remote Communities Energy Use

Remote communities rely heavily on petroleum based fuels for heating, generating electricity and transportation. By definition, these are communities which are not likely to be connected to the main electrical grid or to be serviced by the main natural gas pipeline. In an overview study (Sigma 1983) of British Columbia, 92 eligible remote communities were identified. Total oil products consumption was 4.9 PJ* or 150 million litres per year (32 million gallons), worth 44 million dollars. Commercial energy use was roughly 80% of this total and was primarily for mining and forestry sites. The non-commercial oil used each year was .82 PJ (23 million litres, worth 7.4 million dollars.

Kitkatla Community Energy Use

Kitkatla is a community which is representative of many remote coastal locations (Figure 3). Much of the energy used by the community is in the form of petroleum products brought in by marine tanker. These fuel purchases represent a substantial cash flow from the community, whether from individual members as heating fuel or from the entire community as street lighting, and heat and light for community buildings. Like other communities, Kitkatla can reduce oil dependence through energy management and conservation, and through substitution or replacement of the petroleum products by other energy resources such as wind, wood, small hydro developments and solar energy.

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* PJ: petajoules, 10^{15} joules or 10^{6} GJ.

1.3 Community Description

Kitkatla is a coastal community of approximately 500 people, located on the north edge of Dolphin Island, 60 km by air south of Prince Rupert, B.C. It is a stable community with over 100 residences plus nine other community buildings including churches, schools, community halls, clinic, store, land office, etc. The main industry is fishing, involving 31 boats, 20 of which are rented.

1.4 Climate

The climate of Kitkatla is moderated by the surrounding ocean and is similar to Bonilla Island to the south. Winters are warmer while summers are cooler than neighbouring mainland coastal locations. Bonilla Island temperatures were therefore used for calculations of heat loss and energy use. Prevailing winds in the area are west and southeast, and occasionally reach storm force throughout the winter. Evidence of the wind's strength can be seen where some of the interlocking roof shingles have been torn off buildings.

The island peak lies half a kilometre southeast of the village, and is about 200 metres high. The rounded hilltop is well exposed to winds and trees there are gnarled by the wind.

The low relief of the surrounding islands is likely to increase the availability of winter sunshine relative to Prince Rupert or Kitimat, since the high mountains near these mainland cities tend to cause cloud accumulations. During the site visit, Prince Rupert was overcast with rain, while Kitkatla had broken cloud, high overcast and periods of sun. It was assumed that Sandspit solar radiation data would closely approximate Kitkatla. Sandspit rainfall data were used for the preliminary hydrology evaluation for small scale hydro electricity. Sandspit experiences approximately one half the Prince Rupert precipitation and is likely representative of a "dry year."

1.5 Study Approach

The study commenced with data requests for community energy use, fuel oil supply deliveries, site drawings, air photos, and wind speed measuring equipment from NRC and the B.C. Ministry of Energy, Mines and Petroleum Resources. A site visit was made in November 1983 to conduct the community energy audit and to erect and commission the 20 metre tower and wind recording apparatus. The community energy audit involved inspections of representative house types and ages, the school and teacherages, community halls, stores, and the community diesel electric generator. Climatic data of temperature, precipitation and solar radiation was obtained from Atmospheric Environment Services Canada (AES) for nearby locations of Bonilla Island, Prince Rupert, Kitimat and Sandspit. Wind data records were obtained from AES for the period November 1983 to February 1984 inclusive as they arrived from Bonilla, Lawyer, Lucy and Triple Islands. Wind speed data from Kitkatla was correlated with the other four island locations, where lighthouse keepers recorded hourly wind speeds (Figure 4).

Community energy use data was analyzed and energy conservation options were evaluated. Specific areas of detailed analysis were energy management, building's energy use - especially reinsulation and improved insulation in new construction, heating system improvement, electrical generation, and heat recovery from the diesel generator.

A detailed preliminary wind energy system analysis was made, evaluating four different types and sizes of wind turbines for technical and economic feasibility of generating electricity. Additional energy resources were evaluated for possible applications. In particular, solar energy for domestic water heating was analyzed in detail. A preliminary assessment of nearby potential small scale hydro sites was made and an inventory of nearby potential tidal power sites was made.

The importance of wood as heating fuel is detailed in the energy use portion of the study. Kitkatla has already implemented a major off-oil

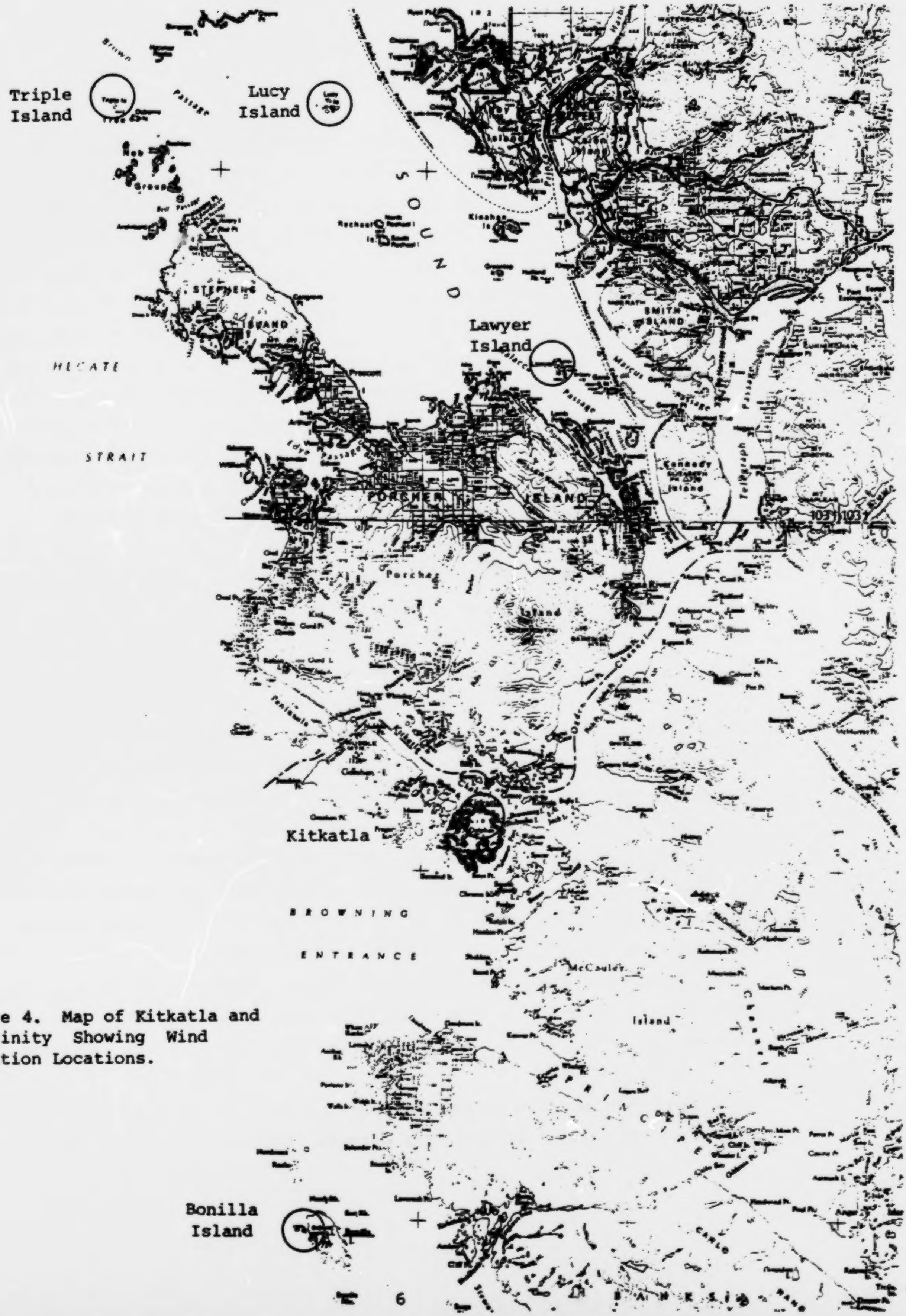
Triple Island
Lucy Island
Brown Passage
SOUND
STEPHENS ISLAND
Lawyer Island
SMITH ISLAND
HECATE
STRAIT
Edye Passage
PORCHER ISLAND
Kennedy Island
Telegraph Passage
Porcher Island
Kitkatla
BROWNING
ENTRANCE
McCauley Island
Bonilla Island
BANKS

Figure 4. Map of Kitkatla and Vicinity Showing Wind Station Locations.

program and could be characterized as a "wood-reliant" community. Wood is the principal energy source for residential heat and displaces between 74% and 81% of the potential home heating oil use.

2.0 CONCLUSIONS AND RECOMMENDATIONS

The principal findings of this study are presented in point form below. In Kitkatla, overall energy use and petroleum product purchases could be reduced through these methods.

2.1 Community Energy Demand and Supply

- Residential and community energy use accounts for 66% to 68%* of Kitkatla energy use; commercial fishboats account for the remaining 32% to 34% (Section 3).
- Oil products accounted for 78% to 81% of energy supplies (Fig. 5)
  Wood accounted for 17% to 18% and
  Solar accounted for 1.5% to 2.9%
- Predicted oil use of 6790 GJ versus actual oil use of 1258 GJ for space heat showed the importance of wood for space heating. Most of the difference was attributed to the use of wood fuel; between 74% and 81% of potential oil use for heat is displaced by wood.
- Predicted community electrical use of 3338 GJ was less than actual generation of 3646 GJ. Some of the electricity was attributed to use for heating homes and water.
- New houses will increase residential oil use by 18.3% per year, and residential electricity at 6.8% per year, if no measures are taken to minimize energy use.
- Completion and occupancy of the civic centre will substantially increase electrical and oil use. Electricity use will increase from 14% to 22%, oil use for heat will increase almost three times, from 1258 GJ/year to 3400 GJ/year.
- Civic centre operation may be a considerable financial liability unless alternatives to oil heat are explored, such as connecting diesel waste heat system, or provision for wood heat.

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* Range occurs since no records of wood use were kept.

Total Energy Supply is 39,245 to 40,510 GJ
(Range occurs since no wood use records exist)

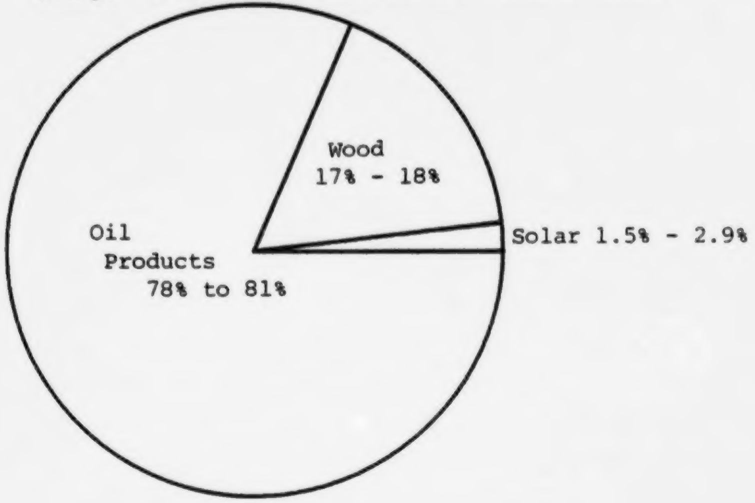

Figure 5. Total Present Energy Use for Kitkatla Community, by Source

2.2 Energy Conservation

- Energy management techniques can significantly reduce individual and community energy use (see Section 4.2 for detailed descriptions.)
- Existing buildings can be reinsulated, weatherstripped, have storm windows added and save considerable energy with paybacks of less than one year to ten or more years. It is recommended that where oil heat is used, measures with five years or less payback be implemented. Where electricity is used, or is used as supplemental heat, measures with ten years or less should be implemented. Community buildings should have longer paybacks, of from ten to twenty years. (Details in Section 4.3 show benefits of changes to each building component.)

- New buildings can save up to half on their fuel use by addition of a "low energy package", with five year simple payback. It is recommended to evaluate the "low energy housing package" approach with future oil heated houses. Incremental cost on a small bungalow was estimated to be $2600.
- The Canadian Home Insulation Program could financially assist homeowners to reinsulate.
- B.C. Hydro's low interest loans for reinsulation will be available and could assist homeowners in funding reinsulation.
- Reorientating 5m^2 (54 ft^2) of glass from the north, east and west sides to the south side of new buildings at the design stage could reduce fuel use by an additional 7.5% and would be free.
- Site planning and wind breaks could reduce heat loss of buildings by reducing wind speeds past houses and buildings.
- Oil heating system improvements and maintenance could save 10% of the annual fuel. Local part-time employment may be available to maintain and tune oil furnaces, subsequent to training program completion.
- If supplementary heat is required, oil use is preferable to electric space heaters.
- Adding additional insulation to water heaters and using oil or propane instead of electricity to heat water is recommended.
- Compared to optimum fuel use, generator fuel use increases by 39% per kWh in the 100 to 110 kW range (25% of full load). Even at 150 kW output (35% of full load), fuel use increases by 13% per kWh.
- Load management, diesel sequencing and power factor correction can reduce fuel use for the generator. Automatic load management and sequencing should be evaluated. A recording kW meter should be installed on the generator output.
- Diesel generator heat recovery appears reasonably well matched to the new civic centre space heating requirements. Additional analysis should be performed prior to installing system hardware.

2.3 Alternate Energy Resources

- Alternate sources of energy are wind, wood, solar and small scale hydro-electricity. Two options exist to reduce electric generator fuel use: a lower-cost lower-savings wind energy option, and a higher-cost higher-savings small scale hydro option.
- An excellent wind resource exists at Kitkatla. From November 24, 1983 to February 21, 1984, the mean wind speed at Kitkatla was measured to be 8.03 m/sec (18.0 mph) while at Bonilla Island to the south it was 8.43 m/sec (18.9 mph). The difference was less than 5%. Bonilla Island is the second windiest long-term measured site in B.C. Long-term wind speeds for Bonilla Island, reduced by 5%, were used to predict long-term output from wind turbines at Kitkatla.
- Four types of and sizes of wind turbines were evaluated for technical and economic feasibility to reduce diesel fuel at Kitkatla; two horizontal axis and two vertical axis machines. The lowest per unit cost was found to be $ .139/kWh from the ESI-54, 80 kW horizontal axis machine. With the Canadian DAF-Indal 50 kW vertical axis machines, costs ranged from $ .36/kWh for two machines to $ .41/kWh for one machine. It is recommended that detailed design work be performed for a wind turbine system.
- The ESI-54 wind turbine would cost $170,000 and save over $30,000 worth of diesel fuel per year.
- Additional wind speed monitoring should be performed for the lower ridge nearer the community to optimize costs of access and power transmission.
- The 50 kW vertical axis wind turbine at Christopher Point, Vancouver Island may be available for re-location at Kitkatla. It is recommended that B.C. Hydro and Power Authority be approached regarding the re-assignment of this machine.

- Wood energy presently contributes between 25% and 27% of the energy for non-commercial use in Kitkatla. As residential heat, wood displaces 74% to 81% of potential oil use. Rather than only burning the wood, the potential for lumber manufacture from wood resources should be evaluated to provide commerce and employment at Kitkatla. Commercially valuable timber is not actively managed at present. Care must be taken to minimize waste if it is harvested for use.
- The Canadian Oil Substitution Program has been effectively utilized by Kitkatla residents and has reduced oil use for house heating purposes by about 50%, through wood substitution.
- Solar energy through windows presently contibutes between 8% and 16% of the household heat.
- Domestic or household hot water can be provided by solar energy on a cost-effective basis if the real cost of fuel for electricity is used in the economic analysis, i.e., $ .145/kWL. It is not cost-effective for homeowners on oil or subsidized electricity ($ .06/kWL) to use commercially available solar water heating systems. Lower cost, homeowner built or installed solar water heaters may be economically viable.
- A preliminary estimate of the potential for small hydro on Porcher Island, north of Kitkatla, indicated a $1.65 million project would save over $160,000/year worth of diesel fuel at Kitkatla. The capital outlay for the hydro project could be reduced if the present generator is not replaced, but serves as emergency standby only. Funds intended for this future replacement could be re-assigned to help offset the cost of a small hydro system.
- A grid connection, tidal and other options were found not to be economically or technically feasible at present. Development of tidal and other systems should be monitored for applicability.

2.4 Energy Policy

- The present policy of discouraging electric stoves should be broadened to minimize the number and use of water heaters, and, where possible, electric clothes dryers.
- Energy policy is required to ensure that electricity sold below cost is minimized. Less than half the fuel cost is presently recovered at current electricity prices. The Band and B.C. Hydro can work in conjunction to develop and implement appropriate policies.
- Housing policy is needed to enable minor incremental insulation costs to be expended to substantially reduce present and future home heating costs, especially for oil heated houses, and for new housing.

3.0 COMMUNITY ENERGY DEMAND AND SUPPLY

3.1 Introduction

The study of community energy use was made to identify the various delivered energy sources, such as petroleum products, propane, etc. and locally available energy sources, such as wood, a small hydro-electric generator, coal or peat, etc. Also identified were the end-uses of the energy supplies, whether for heating homes or schools, or for hot water, providing light, etc. Intermediate energy changes were included, such as diesel fuel being used in the generator to provide electricity to the community.

The quantities of each type of energy were obtained from purchase records and fuel suppliers where available. Electrical generator records, where complete, were used to determine fuel input and electricity produced while billing records showed actual sales. Where wood was used, discussions with homeowners provided estimates; however building heat loss calculations were a more accurate approach to determining annual fuel use. Wherever possible, calculations of energy use were made for large energy users, such as houses and the generator, and were compared to fuel deliveries to verify the accuracy of calculation methods and the assumptions. When predicted and actual energy use did not closely agree, differences were reconciled with calculations of "probable" differences. The results were then used in energy conservation calculations or alternate energy resource analysis for fuel displacement potential.

3.2 Methodology

A one week site visit was made in late November 1983 to install the wind measuring equipment and conduct a community energy audit. The tasks involved were:

- transporting the tower sections, anemometer and recording equipment to the hilltop south of the village, erecting the 20 metre tower and commissioning the recording systems;
- acquiring energy use records, fuel types and deliveries and system information on present energy sources;
- selecting a representative sample of buildings, heating systems and types of fuel, building types - age and condition, insulation levels and data relevant to energy consumption;
- determining types of major electrical appliances used by residents;
- assessing present diesel-electric generation system, with reference to sizes of generators, scheduling, monthly load profiles, and obtaining operating and maintenance records where available;
- identifying physical or site limitations on implementing energy conservation or oil-substitution measures;
- meeting and discussing with Band Council members the future community growth in housing, plans for economic diversification, such as small commercial or industrial projects, and the present economic base of the community, the stability of this base and possible effects on community size and resources.

A meeting was held with the Band Manager to discuss the community energy study and to obtain local assistance in transporting and erecting the tower and wind measuring equipment. Responsibility for the diesel-electric generator, previously administered by the Band, was about to be assumed by B.C. Hydro and Power Authority. Fuel oil suppliers were making the monthly deliveries so a discussion of supply and billing procedures was possible.

The study team inspected six residences, the high school, Band office, store, churches and civic centre for building type and age, insulation levels, fuel types, heating systems, major appliances and water heating requirements. Building degradation due to the severe climate of wind and rain was surveyed. Family size, ages and lifestyle - such as house temperatures, use of doors or windows for fresh air, etc., was determined by observation and discussion with the occupants.

The diesel-electric generators and generator records were inspected and log-book entries were checked. Changes to record keeping were discussed with the generator operators. This was to enable a better idea of daily, weekly and seasonal variations in output to be recorded and made available to the study team. This information was required in order to design a wind turbine system which would be compatible with the diesel system.

A training session was held to instruct a band member in wind equipment data logging and data transfer. Also two sessions were held in the school to involve and educate the younger people of the community, and to hopefully eliminate potential vandalism to the wind measuring equipment by showing pupils the equipment and allowing them to participate in the project process. The project was well received at all levels, particularly by the school pupils.

Additional fuel use data was obtained to complete the records from the site visit, particularly for gasoline and marine fuels. The space heating requirement for various house types was calculated and was found to be one of the major uses of fuel in the community. Another large use was the diesel-electric generator, while the commercial fishboats were the third large user.

Future housing and the associated energy requirements were assessed in projections of future fuel use.

3.3 Kitkatla Energy Supply Data

Petroleum products are delivered, usually once per month, by marine tanker. Diesel oil, stove oil and furnace oil are delivered through a common-pipe system to bulk storage tanks for the generator and for school heating purposes. Private residences purchase stove or furnace oil in steel drums on a cash basis. Gasoline for boats, vehicles, and other uses such as chain-saws, etc. is also delivered in drums. Additional fuel for boats is purchased by owners/leasors in Prince Rupert or other ports, and the estimated annual fuel use was included for reference. Propane is purchased by residents in relatively small quantities. Records of petroleum products were obtained from Imperial Oil, the fuel supplier. Wood is used extensively for space heat. Individuals cut their own wood for fuel, however no records are kept. Estimates of consumption were obtained from residents, and by calculating house heating energy requirements. An estimate of fuel for fishboats was made and has been included in the study as a reference - it is part of the community economy and is a substantial cash flow for those involved, even though there is at present little opportunity for conservation or conversion.

Fuel delivery records are shown in Table 1 for 1980, 1982 and 1983. Two years of recent records are presented plus the 1980 record to show the shift in energy supplies which has taken place. Community fuel deliveries exclude propane which was estimated to be small, irregular and could not accurately be determined. Several observations are pertinent:

- overall increase in generator fuel use is 5% to 6% per year (while population growth has been about 2% per year, and housing growth has been about 7% per year);
- substantial drop in furnace and stove oil for private use between 1980 and 1983; and a
- steady increase in gasoline use since 1980.

TABLE 1
TOTAL YEARLY FUEL SUPPLY - LITRES

Product	Village "Diesel"	Furnace		Stove	Total	Gasoline	Boats
	Generator	"School"	Private	Private	Private		(E)
Year							
1980	355,715	61,142		65,450	78,901(E)	8,722	N/A
			(1,345(E))				
1982	375,292	70,580	11,335	27,758	39,093	9,615	N/A
1983	397,582	48,205	13,558	19,305	32,863	13,267	343,040(E)
Equivalent Energy GJ							
1983	15,227	1,846	520	738	1,258	508	13,138(E)

(E) - Estimate

3.4 Energy Supply and Conversion

3.4.1 Energy Conversion

During the site visit to Kitkatla, data were obtained on specific heating system types, water heating systems and techniques, types of appliances, etc. This data was used to calculate a series of fuel conversion efficiencies which were then applied to the energy demand quantities developed in Sections 3.5. The diesel-electric generator conversion efficiency was also established, from site data and information provided by the equipment supplier. The effect of daily and seasonal load variations on the fuel consumption of the generator could not be evaluated, since generator output had not been recorded in the log book.

Figure 6 shows assumed relative conversion efficiencies of fuel oil to heat using an electric space heater and diesel generator, an oil stove and an oil furnace.

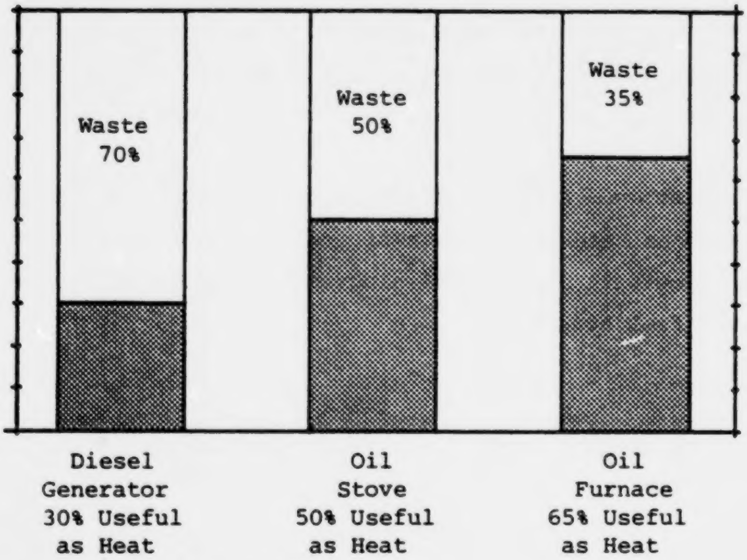

Figure 6. Conversion Efficiency of Fuel Oil to Heat

An electric space heater would supply to the house only 30% of the original heat value in the fuel, 70% would be wasted. An oil stove could supply heat using 50% of the fuel, while an oil furnace would supply 65% of the heat value. Electricity should, therefore, be avoided for heating purposes.

3.4.2 Diesel-Electric Generator

Generating electricity using petroleum fuel engines is a well-established practice in locations throughout B.C. Most larger installations use diesel engines as the prime mover to turn self-exciting alternators or generators. Dual-fuelled systems allow replacement of diesel fuel with gaseous or other liquid fuels. The theory of operation involves matching the electrical demand, or load, as closely as possible in size with the engine-generator equipment (i.e., a high load factor). Decreasing the load or increasing the engine-generator size usually results in an increase of fuel use per kilowatt hour of electricity produced (i.e., poor matching of load and generator capacity reduces engine-generator efficiency). Systems to manage the load are available, but are not widely used.

The theoretical fuel consumption curve for the Kitkatla 420 kW generator has been included in Appendix 3, and shown as Table 2 below. At 400 kW output, 3.08 kWh of electricity are produced for every litre of diesel fuel consumed.

TABLE 2

INCREASE OF FUEL USE WITH DECREASE OF GENERATOR LOAD

Electrical Output kW	Electrical Production/Litre kWh/L	% Increase
400	3.08	<1
350	3.09	0
300	3.09	0
250	3.07	<1
200	2.99	3.3
150	2.78	11
100	2.22	39

There is little difference in fuel consumption between 250kW and 400 kW output. However, at lower outputs, fuel consumption per kilowatt hour increases dramatically. At 150 kW, it has increased 11% and at 100 kW, by 39%.

3.4.3 Kitkatla Generator Operation

The generators presently on site are a: 150 kW, 300 kW, and a 420 kW trailer mounted system. During winter and for most of the year, the 420 kW trailer generator is operated. The December 1983 log sheet is included in Appendix 3. The observed December peak load was 280 kW on December 9 at 5 p.m., while the minimum was 140 kW, 9 a.m., Saturday, December 3. While the 280 kW peak is not likely to be the annual peak, it represents a likely range of the peak demand, i.e., 280 kW to perhaps slightly over 300 kW. The minimum annual load cannot be estimated from these figures, however the recorded "120 kW" figure in the previous pages of the log book is likely to be the minimum demand. Additional daily figures or a recording kWh meter are recommended for a more accurate determination of daily and seasonal electrical demand. The 420 kW generator should not be used for loads less than 200 kW.

3.5 Energy Demand Analysis

The purpose of energy demand analysis was to establish the present community energy use as accurately as possible. A combination of actual fuel delivery records and calculated energy use was required in order to provide both the "whole community fuel use" as well as fuel use, for different houses and heating fuel types. To evaluate various methods of reducing dependence on petroleum products, the following information was required and the procedures below were followed:

- calculation of "typical" energy use for the various buildings inspected, then using these figures to estimate fuel use for other buildings;

- calculation of "typical" energy use for various appliances and hot water;
- fuel delivery figures, from the community and/or the fuel supplier to be compared with predicted fuel use figures;
- fuel prices;
- generator operation and fuel requirements; and
- seasonal variations in population or energy use which would be significant.

3.5.1 Residential Demand Calculation Procedures

The energy overview study (Sigma, 1983) showed that residential energy use in Kitkatla was estimated to be 68% of total community energy use. This study did not assess fuel use by the fishboats.

Household energy use consisted of:

- space heat
- cooking
- hot water, and
- appliances

Space heating is usually the largest residential requirement; the average B.C. house uses over 75% of residential fuel for space heat. Hot water is usually second - about 14% - however many Kitkatla residents were found to be able to do without conventional water heaters. Cooking use averages just over 2% in average B.C. houses, while refrigerators and freezers account for 3% to 4% energy use. Lights and other electrical appliances use 2% and 4% respectively.

Kitkatla residents were found to be relatively independent. Many homes had more than one freezer for food storage so the "provincial average" figures were not applicable without modification.

Space Heating

Energy use for space heating depends primarily on the heat loss characteristics of the building envelope, outside air temperature, inside air temperature, heat produced by people and appliances, and the efficiency of the heating system.

Heat loss calculations involved determining the area of each building component for the six houses surveyed in detail - walls, windows, floor, ceiling or attic, doors, and each component's resistance to heat flow (R value). Also a rate of air change for cold air infiltration was estimated. The air change rate was assumed to be greater than it would be in a less windy location.

The energy use calculation used the total building heat loss coefficient in a detailed computer calculation.* The computer input uses:

- the house temperature during the day, and at night;
- outside average air temperatures for each month during the day, and at night (long-term averages for Bonilla Island);
- heat produced by people and appliances, daytime and night-time;
- heating system type and estimated efficiency; and
- solar radiation data (Sandspit).

This day/night energy use calculation provides an accurate figure for energy savings, accounting for such aspects as lower night-time temperatures, additional insulation, etc. Results of the computer calculations are included in Appendix 1.

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* This computer calculation has been verified against fuel use for a wide range of climate and building types and found to be accurate to within 10%.

Cooking

Average energy used for cooking has been assumed to be equal to the B.C. Hydro and provincial ministry averages of 4.3 GJ/house per year (1200 kWh). While the Band policy discourages electric stoves, wood stoves for cooking contribute significantly to the space heat.

Hot Water

Many houses did not have conventional water heaters. Those which did were assumed to use the average B.C. household amount of energy for water heat, or 24 GJ (6600 kWh).

Appliances and Lights

Many houses had more that one freezer for food storage. Generally homes did not have "convenience" appliances such as clothes dryers and small kitchen appliances. Houses were well lit, in fact lights were often on when not really needed. An average energy use of 20 GJ per house was assumed.

3.5.2 Kitkatla Residential Energy Analysis

Delivered fuel supplies were compared to predicted energy requirements for the community. Fuel use for heat was predicted and compared to actual fuel oil deliveries. Similarly, electrical use was calculated and compared to electrical production obtained by dividing actual fuel deliveries by the fuel consumption per kWh. Wood use was estimated from detailed heat loss calculations on houses. An upper limit to wood use was determined as the difference between predicted and actual fuel use. A lower limit to wood use was determined assuming all of the unaccounted excess electricity was used as space heat.

Building Survey

During the site visit, and from photographs taken of Kitkatla, 106 residential buildings were identified, seven of which are teacherages. Community buildings include the secondary school, old community centre, Band office, two elementary school buildings, two churches, health clinic and the new civic centre building. Five residential buildings were not occupied - burned, under repair or intended for demolition. Two new houses were under construction, while a further three pre-fabricated houses were delivered during the week of the site visit.

Existing houses were arbitrarily divided into four types. Type 1 represents older building practices in place before fuel prices escalated. Walls are structurally sound but with little or no insulation (some had an RSI 1.2 or R7 batt split in half). Floors are generally uninsulated over the crawlspace, while ceilings are only poorly insulated. Doors and windows are not weatherstripped.

Type 2 houses are modest but have some insulation (RSI 1.2 or R7) in all walls, the ceiling and under floors over the crawlspace. Windows and doors fit well and single glass is used.

Type 3 houses have full wall insulation (RSI 2.1 or R12). Attics and floors are also insulated to RSI 2.1 (R12). The crawlspace was sealed and part of it may be insulated. Windows and doors are weatherstripped and storm windows or double glass are used.

Type 4 houses are the most recent. Walls are fully insulated to RSI 2.1 (R12) and attics are insulated to RSI 3.5 (R20). Floors are insulated to RSI 2.1 (R12) and crawlspaces sealed. Windows are double glazed and both windows and doors are weatherstripped. Type 4a could be either a one storey house of 100m^2 floor area with fully heated crawlspace, or a 130m^2 house with a partially finished and heated basement. Both have the same heat loss. Type 4b is a 130m^2 house with a fully finished and heated basement.

A type 5 house was also defined to evaluate the potential impact on future energy use. The impact of this type of house is discussed more fully in Section 4.3. They are the next generation of energy efficient houses which include reduced heat loss through air leakage control. These would be suited to the Kitkatla climate. Walls are RSI 3.5 (R20), attics and floors are RSI 7 (R40). Windows on the north are double glazed with storm windows, or triple glazed. Insulated doors are used and the vapour barrier is caulked and sealed to reduce air leakage and associated heat loss. Type 5 was compared to show the benefits of the additional energy conservation "package," or "low energy" home.

The accompanying Table 3 shows the four existing house types and a Type 5 "low energy" house, heat loss coefficients, annual demand for space heat - the amount of heat required to keep the house warm, and annual fuel use - the demand divided by the annual efficiency of the heating system, whether oil or wood based. Figure 7 compares heat loss coefficients and heating energy demand for the five types of houses.

TABLE 3
Typical House Types, Heat Loss Coefficients and Annual Fuel Use

House Type		1	2	3	4a	4b	5
Floor Area		$80m^2$ (1)	$80m^2$ (1)	$100m^2$ (2)	$100m^2$ (3)	$130m^2$ (4)	$130m^2$ (4)
Heat Loss Coefficient W/^oC		390	281	235	210	274	150
Annual Heat Demand GJ	21/18C	110	71	56	45	69	29
	19/16C		56	43	34	54	
Oil Fuel Use GJ (5)		183	119	93	75	115	49
Wood Fuel Use GJ (6)		244	198	124	100	153	64

(1) One storey house
(2) One storey house plus partially heated crawlspace
(3) One storey house plus fully heated crawlspace, or $130m^2$ house with partially heated basement
(4) One storey house plus fully heated basement
(5) Oil furnace at 60% annual efficiency
(6) Wood stove at 45% annual efficiency

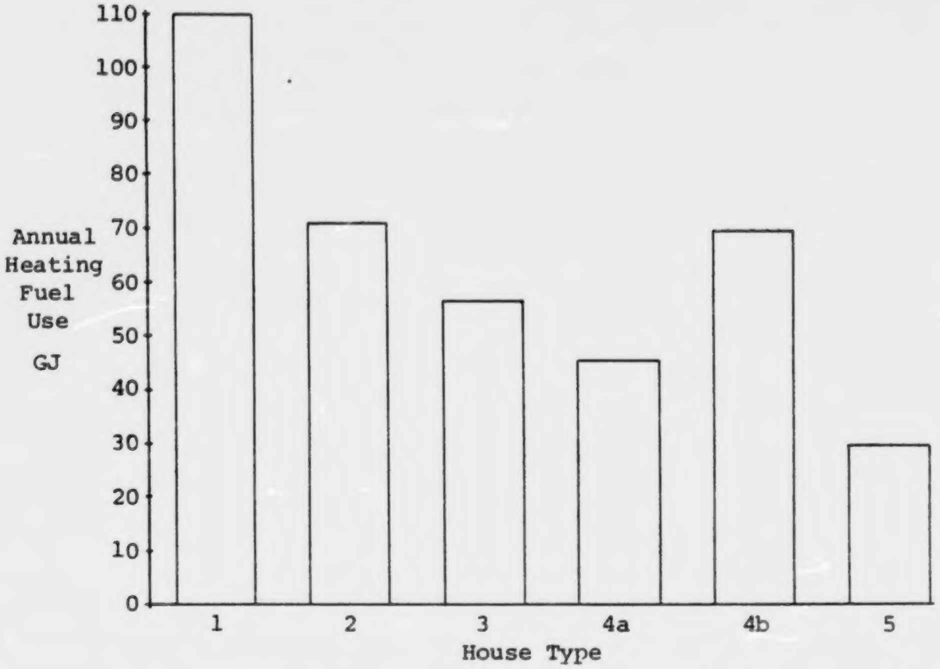

Figure 7. House Type and Annual Heating Fuel Use (Indoor temperature 21/18C)

Predicted* and actual heating oil and electricity consumption for the community are presented in Table 4. The table shows that for 1983, if all houses were oil heated, predicted oil use would be 6790 GJ, versus 1258 GJ purchased fuel. The difference is made up principally by wood, cut by residents, for space heating and cooking. The calculated community electrical demand was 3338 GJ, while the actual generated and used quantity was 3646 GJ. Some of the difference could be accounted for by the use of portable electric space heaters, and generator efficiency at less than 3 kWh/litre of fuel.

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* Predicted energy demands are based on a monthly computer program that accounts separately for internal heat gains (people, cooking, lights, appliances, etc.) and solar heat gains through windows. For all predictions, temperatures are based on long-term means for Bonilla Island, while insolation data are long-term mean values for Sandspit. Year to year variations in weather could result in variations of 10% to 20%.

TABLE 4

PREDICTED AND ACTUAL COMMUNITY PURCHASED ENERGY USE FOR HEAT AND ELECTRICITY

1983 in GJ

		Oil			Electricity	
	Predicted	Error Probability	Actual	Predicted	Error (1) Probability	Actual
Residential	6790	+or-20%	1258	2549	+ (1) - 20%	N/A
Schools and 7 Teacherages	N/A		1846	414	+or-20%	N/A
Other Buildings	N/A		N/A	225	+or-25%	N/A
Community Services	-		-	150	+or-20%	N/A
Generator	N/A		15,227	3646 (2)	+or-10%	N/A
TOTAL			18,331	3338 (3)	+or-20%	

N/A - Not available, not measured or insufficient data to calculate.

(1) - Depends on use of electric space heaters, likely maximum 25%; 708,700 kWh = 2549 GJ

(2) - Predicted delivered electricity based on 3 kWh/L fuel = 4290 GJ possible less 5% for part loading, 5% system losses - lines and transformers, 5% power factor = 3646 GJ.

(3) - Total of "Predicted" column, excluding generator.

The maximum amount of energy provided by wood to the community will be 6790 GJ, less 1258 GJ supplied, or 5530 GJ of oil heat equivalent at 60% combustion efficiency (3320 GJ demand). At 45% wood appliance efficiency, this is 7373 GJ or 410 cords (an average of 5.4 cords per house) per year.

If all of the electricity generated but not accounted for in the calculations were used as a heating fuel supplement, it would be 3646 GJ generated less 3338 GJ calculated or 308 GJ unaccounted for. The minimum community wood use is calculated assuming all of this 308 GJ electricity was used for heating, that is, the oil consumed was supplemented with all of the unaccounted for electricity. When this 308 GJ electricity or 513 GJ of oil equivalent is subtracted from the total predicted fuel requirement difference of 5530 GJ, 5017 GJ of oil requirement remains, or 3010 GJ demand. At 45% wood stove combustion efficiency, this amounts to 6688 GJ of wood heat equivalent, or 371 cords. This amounts to 4.8 cords per house.

Therefore, wood use is between 4.8 and 5.4 cords per house, or a total of between 6688 GJ and 7373 GJ of heat equivalent, presently displacing between 5017 GJ and 5530 GJ of oil. When compared to total residential oil use of 1258 GJ, wood displaces between 74% and 81% of possible residential heating oil. The importance of wood has not generally been determined in most other energy studies.

The solar contribution to heating Kitkatla homes amounts to between 8% and 16% of present space heating demand (see Section 5.4.1) or between 350 GJ and 694 GJ/year, saving between 580 GJ and 1160 GJ/year of oil heat equivalent, and is substantial when compared to the 1258 GJ oil equivalent presently purchased for space heat.

Table 5 presents the various energy supplies to Kitkatla, including wood and solar energy sources for heat. Results of the analysis are shown in Figures 8 and 9.

TABLE 5

PRESENT ENERGY SUPPLY AND USE
Energy Input in GJ

Use	Oil Products	Wood	Solar	Total	Cost
RESIDENTIAL and COMMUNITY					
Diesel Generator	15,227	-	-	15,277	161,577(1)
"School" and Teacherages	1,846	-	-	1,846	17,354(2)
Private - Home Heat	1,258	6,688-7,373(4)	580-1,160	8,526-9,791	11,831(3)
Boats, Vehicles, Saws (Gasoline)	508	-	-	508	6,036
Subtotal	18,839	6,688-7,373	580-1,160	26,107-27,372	196,800
COMMERCIAL					
Fishboats					
- Owned (including store supplies)	6,404(E)			6,404	76,000(E)
- Rented	6,734(E)			6,734	80,000(E)
Subtotal	13,138	-	-	13,138	156,000(E)
TOTAL	31,977	6,688-7,373	580-1,160	39,245-40,510	352,800

Energy Costs
Under Direct Control = Community-School = $196,800-$17,354 = $179,445
or $1,850 per household

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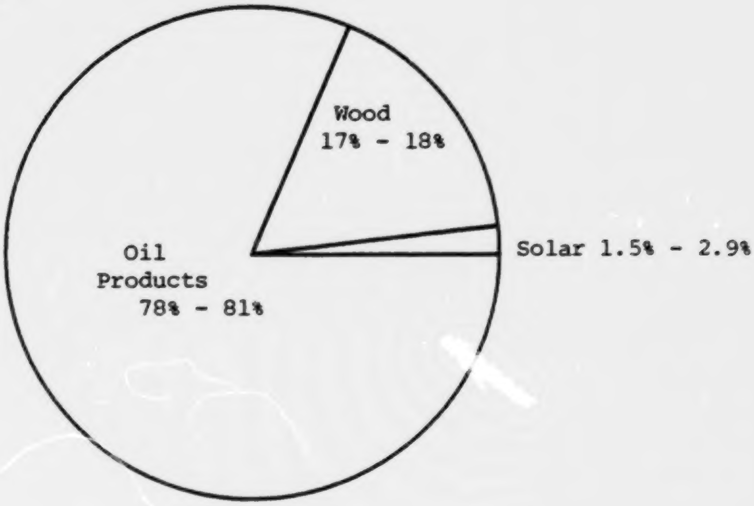
(1) INAC Assistance
(2) Not paid for by community - school district funds.
(3) Oil only, no cost attributed to wood.
(4) Range depends on use of electricity for space heat.
(E) Estimated values, based on approximate figures, provided by Kitktla community members.

Energy Sources



Energy Uses

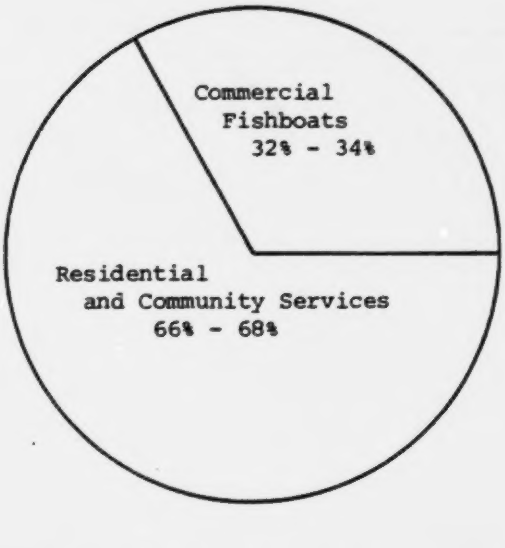
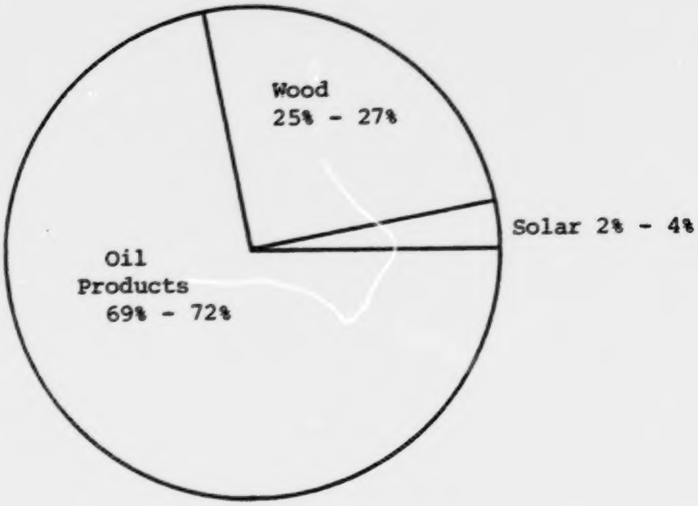


Figure 8. Total Energy Supply and Demand for Kitkatla Community, Energy Sources and Energy Uses

Energy Sources



Energy Uses

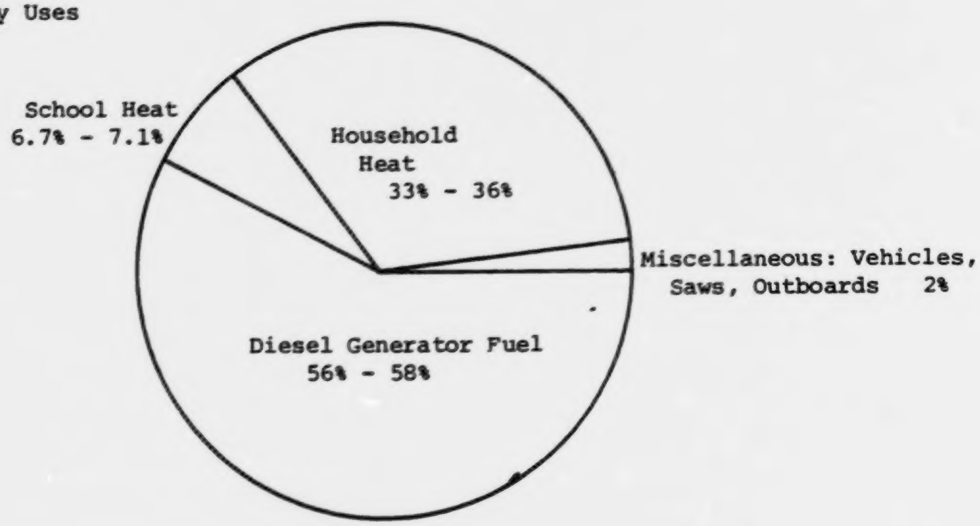


Figure 9. Non-Commercial Energy Sources and Energy Uses
Total Energy 26,107 GJ - 27,372 GJ
(Range due to no records for wood energy)

3.5.3 Non-residential Energy Demand

The fishboats used 32% to 34% of the total community energy requirements and are thus the major non-residential energy user.

The next principal non-residential demand was for heating and lighting community buildings or commercial ventures. Community commerce is limited to several small stores and home-baking, rather than a large energy user. Buildings accounted for most of the energy demand - a large school, two smaller schools, two churches, an older community hall, Band office, and health clinic. Street lighting and the water and sewer systems also require energy. In future, the new civic centre will require energy for both heating and lighting.

Fuel deliveries for the school and teacherages were available as aggregated quantities, and labelled "school." Where fuel use data for other buildings could not be separately identified, buildings were treated as "equivalent households" for space heating, thereby providing an accurate estimate of the space heating as the predominant energy requirement.

Other energy requirements - street lighting, water, sewage, etc. - were calculated from installed system specifications and estimated hours of operation (Appendix 1.2).

3.6 Future Energy Requirements

The housing stock will be supplemented by Type 4 houses, at the rate of seven per year; three oil heated and four wood heated. This will add 220 GJ/year to oil use, or 18.3% per year increase in the residential sector. It will also add 250 GJ/year to the present electricity use, 3646 GJ, or a growth rate of 6.8%.

The civic centre will also require heating and lighting and has been estimated (Spaceworks, 1983) to require 2200 GJ of heat and from 500 to 800 GJ of electricity for lighting, and a 40 kW to 50 kW increase in generation capacity.

Addition of the civic centre could increase fuel oil use from 1258 GJ to 3400 GJ, almost a three-fold increase. The electricity increase would be from 3646 GJ to at least 4150 GJ and perhaps to 4450 GJ, increases of 14% to 22%.

4.0 ENERGY CONSERVATION: TECHNICAL AND ECONOMIC EVALUATION

4.1 Introduction

The principal focus of the study is to reduce oil use in non-grid communities. In that context, there are two conceptually different ways to save oil. One is to change the way of operating - appliances, furnaces, or buildings which require energy; the other is to actually change or improve the building, furnace or appliance by adding insulation or other energy saving features. The former is the "energy management" method, the latter is the "technical fix" method.

The first approach involves decisions and choices such as: How warm should the building be? Does the light need to be on or can the drapes or curtains be left open so the sun can help to heat and light the space? Many opponents to energy conservation believe the quality of life or comfort will be sacrificed to save energy. Provided that the occupants can afford the energy and that the cost of energy will not affect their lifestyle, they do not need to sacrifice comfort - turning off a light in an empty room is an example.

The second method, of "technical fixes", requires an economic evaluation to determine whether spending money on a change will save enough energy to pay for the cost. Insulation or reinsulation, adding storm windows, or heat recovery on the diesel generator, are typical methods of saving purchased energy, and must be evaluated for cost-effectiveness.

4.2 Energy Management

The following management methods can be used to save energy.

Residential and other Buildings:

- reducing the indoor temperature, and using a lower temperature "setback" at night;

- closing doors and windows while the building is heated;
- avoiding electrical use for heating, using oil (or preferably wood) instead;
- reducing the water heater tank temperature, and amount of hot water used (especially if a water heater is electric);
- turning off lights and television or other appliances when not needed;
- opening curtains on south-facing windows to let the sun in for light and heat.

Generator:

- scheduling and sequencing generators so that they are operated in the 60% to 100% load factor range, rather than the existing 25% to 65% range.

Energy management also concerns inter-fuel substitution - wood, oil and electricity. In the previous analysis in Section 3, approximately 308 GJ of electricity could not be accounted for. If this is consumed as electricity for space heat, it would represent a consumption of 28,541 litres of diesel fuel (at 3 kWh/L). If it were burned directly in furnaces, it would represent 13,402 litres of diesel fuel. Therefore, residents should be encouraged to burn the oil directly for heat. One problem is that the electricity price to the customer is almost the same as the oil price, even though the cost of producing the electricity is higher. This means that there is little benefit to the homeowner in using less electricity because it costs about the same and is more convenient than oil.

A computer analysis was made to determine the effect of house temperature on fuel use. For the analysis, a Type 3 house was selected as representative of most of the buildings. The effect of inside temperature on annual fuel use, assuming oil heat, is presented in Table 6 following.

TABLE 6

Effect of Indoor Temperature on Fuel Use for House Type 3

Temperature Day/Night °C	Heating Demand GJ/year	% Increase of Fuel Use over base
21/21	66.4	53.5
21/18	55.9	29.1
21/16	49.3	13.9
19/16 (Base)	43.3	0

The 19/16°C temperature was used as a basis for comparison, since it is the most probable "equivalent temperature" regime of the houses. Much of the family time is spent in the kitchen area, while unused bedrooms are not heated during the day. The living room area is the other principal family space and with a wood heater, either alone or supplementing oil heat, this room will be warmer than unheated rooms and at a comfortable temperature. The result is an effective heating strategy - not all rooms are constantly heated, and a modest amount of fuel is used. By comparison, a central oil furnace providing a constant 21°C throughout the house would require over 50% more energy. The importance of inside temperature is clearly seen, and occupants can benefit by keeping the temperature low, both day and night-time.

4.3 Reducing Building Heat Loss

Existing Buildings

In this analysis, heat loss and fuel use calculations were made for each of the four existing building types, and for the "low energy" building style.

New heat loss and fuel use calculations were made for "improved insulation" levels in these same buildings, and were compared to the original fuel use data. The energy savings were determined as the difference in fuel use. This was done for each component of the house and results are shown in Table 7.

TABLE 7

Energy Conservation in Existing Buildings (1)

Reinsulation Cost/Benefit

Building Component	Initial	Add RSI (R)	Saves(2) $/year	Cost(3)		Simple Payback	
				Materials $	Installed $	Materials Years	Installed Years
Walls	Uninsulated	2.1 (12)	349	292	456	.84	1.3
Windows	Single	Add storms or replace with double	184	20-1000	2000	1-5	11
Floor	Uninsulated	2.1 (12)	1362	332	518	.25	.4
		3.5 (20)	1431	553	864	.4	.6
	1.2 (R7)	3.5 (20)	237	553	864	2.3	3.6
	2.1 (R12)	3.5 (20)	133	553	864	4.1	6.5
Attic-Ceilings	1.2 (R7)	3.5 (20)	284	553	864	2	3
		5.6 (12+20)	317	885	1382	2.8	4.4
	2.1 (R12)	3.5 (20)	121	553	864	4.6	7.1
	3.5 (R20)	3.5 (20)	77	553	864	7.2	11

(1) One storey bungalow - 36' x 24', 80 m^2 (864 ft^2): For larger floor areas, multiply by increase in floor area (payback will not change significantly).

(2) Assumes oil heat at 60% annual efficiency; oil at $ .36/L.

(3) Insulation is done all at once on a number of homes; cost is 15 times Vancouver.

Costing data was obtained for various energy saving measures - ceiling or attic insulation, wall insulation, floor insulation and storm windows. Simple payback ranges from less than one year to over ten years for replacement windows and adding RSI 3.5 (R20) to an already insulated ceiling at RSI 3.5 (R20).

From Table 8 following, the diminishing returns of adding insulation is shown. For an 80m^2 (864 ft^2) attic/ceiling, the figures show how adding RSI 3.5 (R20) insulation to existing RSI 1.2 (R7), to RSI 2.1 (R12), or to RSI 3.5 (R20) results in decreased savings.

TABLE 8

Diminishing Returns from Additional Insulation

Initial Insulation Level	Added Insulation	Savings $/year
RSI 1.2 (R7)	RSI 3.5 (R20)	284
RSI 2.1 (R12)	RSI 3.5 (R20)	121
RSI 3.5 (R20)	RSI 3.5 (R20)	77

The less insulation there is in place to begin with, the greater the potential savings. RSI 1.2 increased by RSI 3.5 will save $284/year, while RSI 2.1 increased by RSI 3.5 would save roughly half.

Reducing the air leakage of buildings will reduce fuel use. Actual savings cannot be predicted accurately, however, adding good quality weatherstripping to all doors, windows and attic hatches, closing in the crawlspace, and not using windows for venting will be free or low cost measures with short paybacks.

New Buildings

Buildings can be more easily upgraded at the design stage. Ceiling, attic and floor insulation levels are easiest and least expensive to increase, but walls can be designed to reduce heat loss. A major reduction in energy use through reduced air leakage can be achieved at both the design stage and through careful workmanship during construction. Typical construction details to reduce air leakage have been included in Appendix 2, taken from manuals prepared by SAR Engineering for B.C., Canadian and U.S. housing authorities.

This combination of "low energy" measures has been evaluated for potential application to future houses at Kitkatla. Results of heat loss calculations and savings are presented below in Table 9. Measures were considered to be applied simultaneously, that is, as a "package" of energy saving measures.

TABLE 9

Energy Conservation in New Buildings
New House Insulation - "Low Energy House" (Type 5) (1)

	Initial	Final	Savings $/year
Walls	RSI 2.1 (R12)	RSI 3.5 (R20)	307
Windows	Double	Triple	58
Attic/ Ceiling	RSI 5 (R28)	RSI 7 (R40)	31
Air Change	.5/hour	.2/hour	127
			523

(1) Based on modest $80m^2$ bungalow (864 ft^2).

The added cost of the "low energy" package is approximately \$2/ft^2 of floor area in Vancouver, increased 50% for Kitkatla (build or deliver), or \$3/ft^2. Therefore, the incremental cost is \$2592 and the savings are \$523/year, resulting in a simple payback of five years.

4.4 Buildings and Solar Exposure

A series of computer calculations was made to evaluate the potential to reduce heating oil by moving windows of new houses from the north, east and west sides to the south side. The results showed that, provided trees did not obstruct the sun, adding 5m^2 (54 ft^2) of south-facing glass would save about 7.5% on the fuel used. If this was done at the design stage of the new houses, there would be little or no additional cost involved.

This 7.5% is in addition to the 8% to 16% range of solar energy contribution to house heat which already occurs in existing buildings (Section 5.4).

4.5 Buildings and Site Planning

Because of the prevailing winds and cool climate of Kitkatla, advantage could be taken of favourable siting to reduce heat loss, especially due to exposure to winds and the associated air leakage heat loss. The present method of completely clearing areas prior to adding new housing results in increasing the buildings' exposure to wind in those locations. While existing trees may create hazards during storms, replanting with shorter cedars or deciduous trees will help reduce wind speeds adjacent to the houses. Care must be taken to avoid planting where future growth will create shadows and block sunlight which could be useful to help heat the buildings.

4.6 Heating System Improvement

In addition to the reinsulation of existing buildings, or added insulation to new buildings, the heating system can frequently be improved. Oil furnaces will have soot accumulate on the inside of the heat exchanger; dust and dirt on the outside and on the fan; filters will get dirty and reduce airflow across the heat exchanger; distribution ducting may be uninsulated, poorly insulated or leaky; or airflow may be poorly balanced and unequal at each outlet. Maintenance of the furnaces will allow residents to get the best performance. Combustion efficiency can often be improved between 5% and 10%, and when combined with other measures, at least a 10% savings should result.

For the Type 4 houses using 95 GJ worth of oil per year, approximately 9 GJ could be saved, worth $85 a year, by combustion tests and maintenance. Even servicing every two years should result in money saved after paying for servicing. A local resident, with technical training, would be well suited and could find part-time employment.

Residents should use oil instead of electricity for space heaters. Electricity may be more convenient, however almost twice as much diesel oil as furnace oil is needed because of the lower generator efficiency.

Chimneys and flues should be maintained, mainly for safety. Both oil and, especially, wood heaters require routine maintenance. The use of wood for heat is discussed separately in Section 5.3.

4.7 Water Heater Improvements

In addition to furnaces, water heaters can also be improved to reduce losses and operating costs. Flow restrictors for showers will not noticeably reduce water flow, but can make a finer spray and use much less water. Plastic flow restrictors cost only a few cents to a dollar and are effective; B.C. Hydro will provide the restrictors free and state they can save up to 50% of hot water use and water heat. Additional insulation around the tank will reduce standby losses by about 50%. Either insulation batts and plastic sheeting can be taped in place or a "water heater insulating blanket" can be purchased.

It is possible to reduce the peak demand for electricity by disconnecting the upper element or reducing the rating of one or both of the elements of electric water heaters. These modifications would reduce the rate of water heating and perhaps inconvenience some people. Alternatively, timers could be used to turn on water heaters at off-peak generating times. An additional recommendation is to use oil or propane fired water heaters - they have faster heat recovery than electrical water heaters and because of the lower electric generator efficiency, use approximately half the oil needed at the electric generator.

4.8 Diesel-Electric Generation System - Operation and Improvement

The average and range of recorded generator loads are shown in Table 10 below for the period December 1, 1983 through December 23, 1983, as taken from Appendix 3. Figure 10 shows the percentage of fuel increase per kilowatt hour as a function of generator load in kilowatts.

TABLE 10

Diesel Generator Loads Dec. 1, 1983 to Dec. 23, 1983

Time of Day	0800 to 0900	1200 to 1300	1700 to 2000
Average Generator Output	190	214	236
kW Range	140 to 240	200 to 240	200 to 280

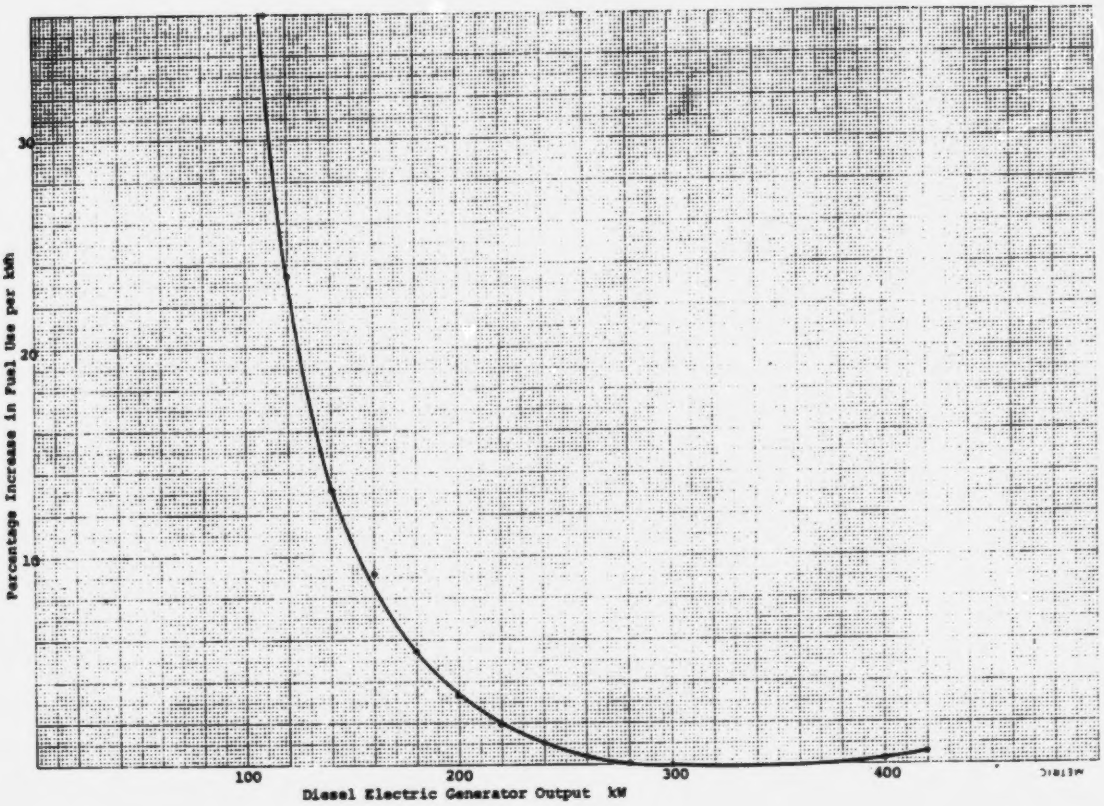


Figure 10. Percentage Fuel Increase per kWh as a Function of Diesel Generator Load.

When fuel consumption was calculated, the morning fuel use increased by 5%, mid-day use by 2.5%, while evening use increased by 1.4% relative to full load efficiency. At night, reduced loads are likely and fuel consumption per kWh will increase by more than 5%. It was concluded that much of the time, the present generator is operated at reduced output, thereby unnecessarily increasing the fuel consumption per kWh of electricity produced.

Sequencing the Generators

An assessment should be made of the opportunity to use the smaller generators to improve fuel efficiency - for example, using the 300 kW generator in spring and fall and the 150 kW generator in summer. Auto phase synchronization is the preferable method of coupling two generators so that one does not need to be stopped before starting the other. This approach would involve installation of a phase synchronizer control, costing $10,000 to $12,000 installed. Alternatively, an automatic start, auto load synchronizer would cost approximately $25,000 installed.

If the average winter daytime load is 213 kW, and the average night-time load is less than 190 kW, at least 5% fuel could be saved at night during winter (assuming the 300 kW generator produces no less than 3.09 kWh/L of fuel). During the balance of the year, assuming night-time demand is in the 140 kW range, about 13% of the fuel could be saved by matching the generator to the demand.

Although records are insufficient at this time, demand studies of other communities (JBF Scientific, 1983) indicate at least a two to one ratio between winter and summer peak demands. This is reasonable assuming that some electric space heaters are used in winter. Therefore, summer day and night savings are likely to be in the 13+% range. Over the year, savings of the order of 8% are likely. If 8% of the generator fuel could be saved, it would be worth over $12,000 per year at this time. This indicates a potential payback of less than one year for the simple system and two years for the automatic system. These options appear to be sufficiently attractive financially that further assessment should be made. This would consist of a measured determination of fuel consumption data for the 420 kW and 150 kW generators, demand over the year, savings potential, and the cost of rebuilding or overhauling the 150 kW generator. A recording kW meter should be installed as soon as possible to enable such an analysis to be made.

Load Management

As electrical use increases, especially with electric water heaters installed in new housing, the peak demand on the generator may increase. If the daily peaks can be reduced, the generator can run more closely matched to a steady load, and within a fuel efficient range. Water heaters can be controlled automatically by timers or remote switching to level the load, or to reduce peak loads by "peak shedding." This in turn would make the sequencing strategy previously discussed even more effective by reducing start up and shut down procedures.

Power Factor

The power factor could be improved and is likely due to the inductive loads of school and other fluorescent lighting, pumps, fans, and refrigerators. During the site visit the power factor was observed to be 90% to 95%. A 5% to 10% reduction in energy use could be achieved by power factor correction.

4.9 Diesel Generator Heat Recovery

Waste heat from the diesel generator, in the cooling jacket water and in the exhaust gases, can be extracted and used to displace building heat from oil or electricity. The present 420 kW generator was designed, and equipment put in place, to recover heat from the engine jacket cooling water, rather than use the radiator to eliminate engine heat. The generator can therefore produce heat for the new civic centre. Considerable piping to the centre will be needed however, when the centre is ready for heat. Money was saved with this foresight of specifying heat recovery equipment when the diesel engine was ordered compared to the cost of adding heat recovery equipment later, on site in a remote location. Until the centre is closer to completion and ready for use, the exact savings of heating oil are difficult to determine. Assuming about 70% of the generator waste heat can be used, and that 25%

of the input fuel is converted to jacket water heat, up to 2670 GJ of useful heat could be extracted and applied to the civic centre. This may be sufficient to displace nearly all of the predicted 2200 GJ of heat required (Spaceworks,1983). It should be noted that heat may be available from the generator when not needed by the civic centre. The potential exists for a reasonable match between energy required by the civic centre and available waste heat from the generator.

We recommend a detailed analysis to analyze daily and seasonal peaks; energy demand by the civic centre and energy supply by the diesel-electric generator.

4.10 Heat Pumps

Unless space heating or water heat is already provided by electricity, the advantages of heat pumps do not outweigh the costs and technical factors. Under the coldest conditions, auxiliary heat would be provided by electric resistance heaters, increasing the peak load on the diesel generator. Few, if any, buildings are electrically heated and as equipment costs are high for heat pumps, it is unlikely that heat pumps would be economic, or appropriate due to servicing and maintenance.

5.0 ALTERNATIVE ENERGY RESOURCES

5.1 Introduction

The second method to use less petroleum based fuel in the community is to replace it with substitute fuels or energy sources. One such resource with good potential is wind, harnessed to produce electricity to supplement the diesel-electric generator. Kitkatla's exposed location and proximity to Bonilla Island, the second windiest site in B.C., presented an opportunity to evaluate this potential in detail and is the focus of this Section.

Other resources were also evaluated. The present range of wood use was calculated in Section 3.5 but additional potential and the importance is briefly discussed here. The potential for and present extent of solar energy is evaluated, particularly with reference to providing domestic water heat for homes. Additional alternatives are discussed briefly; these include hydro electricity, a review of the grid extension evaluation by B.C. Hydro, tidal power and other fuels such as compressed natural gas (CNG) to replace diesel fuel and perhaps furnace oil for the school.

5.2 Wind Energy

5.2.1 Introduction

The available wind energy resource in B.C. is most concentrated along the coast and on exposed hilltops in the interior. A study of the potential for B.C. (ESL/1B1, 1981) indicated several locations of favourable wind resources. More recently, a study of alternate energy for off-oil generation of electricity (Acres, 1983) drew incorrect conclusions about wind energy potential, especially that the cost of $ .40 to $ .50/kWh cannot be substantially reduced for B.C. locations. In California, several thousand second and third generation wind turbines are selling power to electrical utilities. In many cases, both wind speeds and fuel cost in California are less favourable than B.C. coastal locations (i.e., better winds and higher fuel costs occur at B.C. sites).

Both horizontal axis and vertical axis "eggbeater" wind turbines are technically developed as reliable energy producers with modest maintenance required.

5.2.2 Wind Resource

A study of B.C. locations (SAR, 1977) revealed that Bonilla Island and Triple Island on the northwest coast of B.C. had the second and third highest wind speeds in B.C. and wind power potential. The long-term mean annual wind speeds of Bonilla and Triple Islands are 8.3 metres/second and 7.6 metres/second respectively. Kitkatla, on the north edge of Dolphin Island, is 35 km north and just east of Bonilla Island. Surrounding islands are low and the exposure of Dolphin Island is very favourable to prevailing winds and thus to available wind energy.

5.2.3 Kitkatla Wind Measurement

The objective was to measure wind speeds on the hilltop of Dolphin Island, adjacent to the Kitkatla community, for a relatively short term of several months, and to compare wind speeds at Kitkatla with wind data from Atmospheric Environment Services Canada for lighthouses on Bonilla, Lawyer, Lucy and Triple Islands (Figure 11).

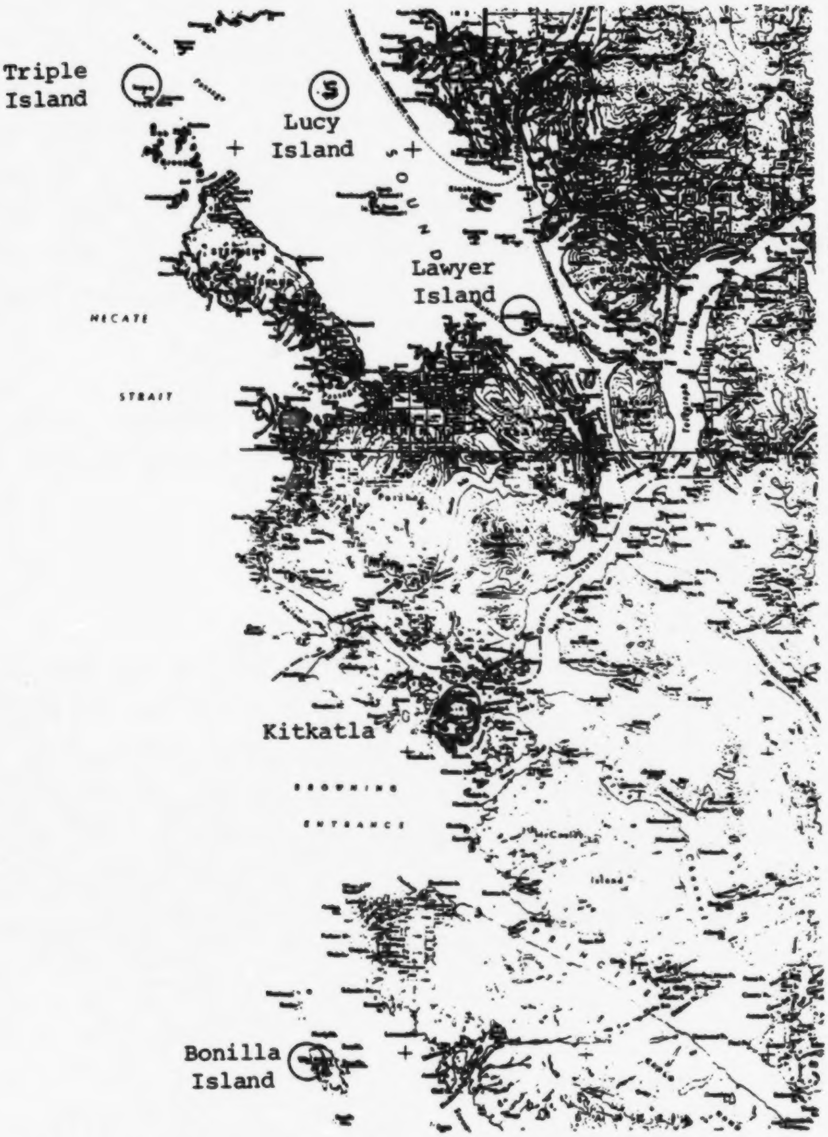

Triple Island
Lucy Island
Lawyer Island
HECATE
STRAIT
Kitkatla
BROWNING
ENTRANCE
Bonilla Island

Figure 11. Map Showing Wind Station Locations

Two sets of data were collected at Kitkatla: hourly averages of one minute recorded data logged by a Campbell Scientific CR21 data logger and a cassette tape recorder, and wind data every two seconds logged by a wind histogram recorder, on loan from NRC's Wind Energy Research Program.

Two-second data was recorded and analyzed twice per month as weather, equipment and manpower permitted, while hourly data was forwarded on cassette to SAR Engineering in Vancouver for direct comparison with hourly data for lighthouses. Lighthouse data was obtained as hard copy - a photocopied record of daily wind charts with the 24-hourly values.

Both the hourly and two-second wind speed data were compared with the light station data (Appendix 4). From this comparison, one "representative" light station was selected which most closely matched the actual Kitkatla data. A correction factor was applied to reduce the mean wind speed at the light station to make it comparable with the Kitkatla data. The mean Kitkatla wind speed, for the period monitored, was 5% less than for Bonilla Island.

Long-term Bonilla light station data was then decreased by 5% and this "modified" data was used in calculation of long-term output of a wind turbine system at Kitkatla.

5.2.4 Data Analysis

Short-term wind data from Kitkatla was compared to corresponding data from Bonilla, Lawyer, Lucy and Triple Islands lighthouses in several ways.

Criteria for choosing the best correlation between Kitkatla and lighthouse data were:

- Observed mean wind speed for the entire wind data collection period at Kitkatla should be closely matched by the lighthouse wind data for the same time period.
- Monthly mean wind speeds for the lighthouse should also closely match the Kitkatla data.
- Bi-weekly mean wind speeds for the lighthouse should closely match Kitkatla data.

Due to weather patterns and moving frontal systems and associated variability, it was postulated that hourly correlation of wind speeds at five different locations was not likely to be a significant factor in long-term energy output; bi-weekly, monthly and full-period wind speeds were more significant and appropriate comparisons.

Table 11 shows mean wind speeds at Kitkatla and the four lighthouses for various time periods. Figure 12 presents these wind speeds graphically.

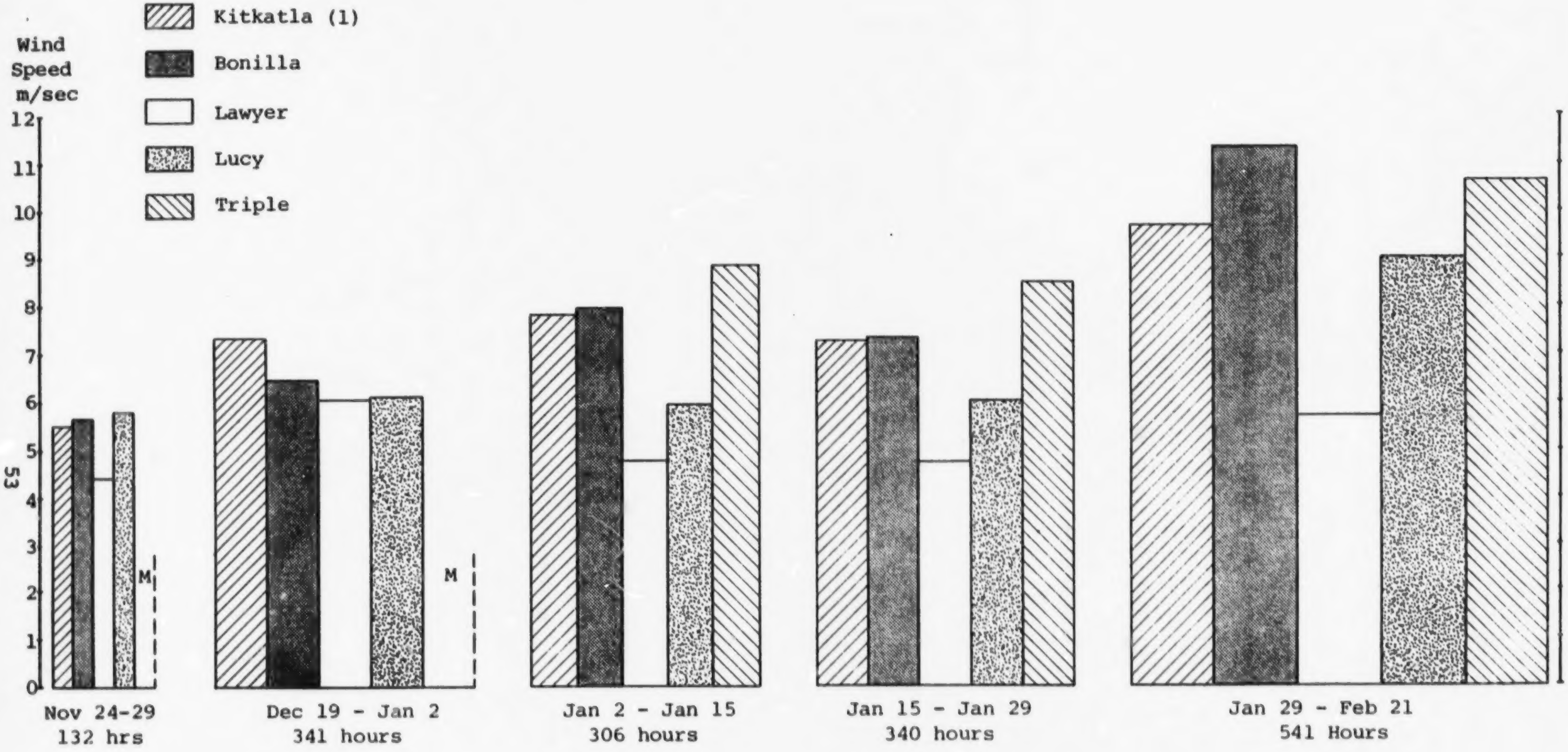
TABLE 11

Mean Wind Speeds for Five Study Sites, m/sec

Period	Hours of Data	Kitkatla(1)	Bonilla	Lawyer	Lucy	Triple
Nov. 24-29	132	5.55	5.66	4.40	5.80	M
Nov. 29-Dec. 19	478	M	-	-	-	M
Dec. 19-Jan. 2	341	7.34	6.44	6.02	6.15	M
Jan. 2-Jan. 15	306	7.80	7.94	4.77	5.85	8.86
Jan. 15-Jan. 29	340	7.26	7.32	4.73	6.03	8.51
Jan. 29-Feb. 21	541	9.68	11.35	5.67	9.01	10.66
"Full Period"						
Nov. 24-Feb. 21 (missing Nov29-Dec19)	1660	8.03	8.43	5.28	6.97	N/A
Jan. 2-Feb. 21	1187	8.50	9.32	5.17	7.34	9.58
"January"						
Jan. 2-Jan. 29	646	7.52	7.61	4.75	5.94	8.68

(1) Mean wind speed from two-second bins of wind histogram recorder.

M - Missing data due to equipment malfunction.



(1) Kitkatla mean wind speed from Wind Histogram Recorder, other data hourly from AES anemographs.
M Missing data at Triple Island due to anemograph malfunction.

Figure 12. Chart of Mean Wind Speeds for Five Study Sites, from Nov. 24, 1983 to Feb. 21, 1984

Additional weekly comparisons of mean wind speeds and Weibull coefficients k and A, were intended. These were to be based upon corresponding hourly wind data at Kitkatla and the four lighthouses, using the Campbell Scientific CR 21 datalogger at Kitkatla and the data from Atmospheric Environment Services Type 45B anemometers at lighthouse locations. The CR21 was installed in parallel with the wind histogram recorder and used a cassette tape system for data recording. Equipment malfunctions, especially the loss of tape recorded data due to "noise" obliterating the data signal, and loss of high wind speed data (over 16 m/sec) due to buffer overflow of data with the CR21 datalogger, prevented meaningful correlations from being made on the hourly Kitkatla data. Appendix 4 shows Weibull coefficient correlations for low wind speeds where overflow was not substantial.

The wind speed comparisons made over the various time periods in Table 11 are valid, since they were based on the two-second scan data recorded by the histogram equipment for corresponding light station data over the same time periods. Detailed data and analyses are found in Appendix 4.

5.2.5 Wind Data Results

For the period of monitoring, excepting November 29 to December 19 data loss due to equipment failure, the mean wind speed at Kitkatla was 8.03 m/sec. The corresponding speed for Bonilla Island was 8.43 m/sec, a difference of less than 5%. For Triple Island, due to missing data, only January 2 to February 21 data could be compared. For this period, Bonilla Island was 9.6% greater than Kitkatla, while Triple Island was 12.7% greater. Lawyer and Lucy Islands mean wind speeds were significantly less than Kitkatla. Lawyer Island was 52% lower and Lucy Island was 15% lower.

A detailed comparison of mean wind speed data for Kitkatla with Bonilla Island and with Triple Island is shown in Table 12.

TABLE 12

Comparison of Kitkatla with Bonilla and Triple Islands Wind Speeds
Wind Speeds, V - m/sec
Differences %, + or - with respect to Kitkatla

	Kitkatla (1)	Bonilla		Triple	
	Speed	Speed	Difference	Speed	Difference
Nov. 24-Nov. 29	5.55	5.66	+2%	M	M
Dec. 19-Jan. 2	7.34	6.44	-14%	M	M
Jan. 2-Jan. 15	7.80	7.94	-1.8%	8.86	+13.6%
Jan. 15-Jan. 29	7.26	7.32	+ .8%	8.51	+17.2%
Jan. 29-Feb. 21	9.68	11.35	+17.3%	10.66	+10.1%
"Full Period" Nov. 24-Feb. 21 (missing Nov29-Dec19)	8.03	8.43	+5%	M	N/A
Jan. 2-Feb. 21 (Triple Island complete)	8.50	9.32	+9.6%	9.58	+12.7%

(1) Based on wind histogram record data.

It was therefore concluded that using long-term mean wind speed as measured at Bonilla Island would represent a good approximation to mean wind speeds at Kitkatla, provided the Bonilla Island speed was reduced by 5%.

5.2.6 Preliminary Analysis of Wind Power Feasibility
Wind Turbines Available

There are presently few large wind turbines in B.C., however, considerable development and operating experience has been done elsewhere. During the past three years, over 3800 wind turbines with an installed capacity of over 260 MW have been installed in California and are contracted to deliver electricity to utilities, as detailed in Appendix 4. A number of turbines have undergone sufficient field demonstration to have proven reliability and known maintenance costs.

Manufacturers were contacted and have provided cost and performance data for machines. Two types and two sizes of wind turbines were evaluated for Kitkatla:

- one 100 kW vertical axis type;
- one and two 50 kW vertical axis types;
- one 80 kW horizontal axis type; and
- one and two 45 kW horizontal axis types.

This selection provided a cross-section of proven machines in types and sizes. Machines and manufacturers are shown below:

Capacity	Type	Manufacturer
100 kW	Vertical Axis	Flo Industries
50 kW	Vertical Axis	DAF Indal
80 kW	Horizontal Axis	Environmental Sciences Inc.
45 kW	Horizontal Axis	Enertech Wind Systems

Technical Considerations

Diesel Loading

The total wind turbine capacity was selected on the basis that it should approximately equal the minimum diesel generator load at present (see Section 3.4.3). This would provide for maximum use of wind turbine output. A review of the generator log book showed that "120 kW" was used consistently as the figure in the "kilowatt" column of the log. A day-by-day record was requested for morning, noon and evening inspections, with actual generator loads to be recorded during the study (see Appendix 3).

From December 1 to December 31, 1983, the minimum recorded load was 140 kW, Saturday, December 3 at 9:00 a.m. Maximum load was 280 kW, Friday, December 9 at 5:00 p.m. More detailed records are still required, over a period of one year, however it is likely that the minimum average load is aproximately 100 kW. Therefore, one or more wind turbines totally up to 100 kW were selected for preliminary analysis.

In actual operation, there will be times, at night during summer, when strong winds combined with low electrical load may necessitate some "dumping" of excess electricity from the wind turbine. Such periods will be short and followed by more moderate winds, allowing the diesel generator to resume normal operation. Provided such periods of excess generation by the wind turbine(s) are short, no negative impact on diesel operation should occur.

Motor Starting

The wind turbines selected all use induction generators. During start up, in-rush current will cause some lowering of the line voltage. For a 300 kW diesel generator, an 80 kW induction generator will cause approximately a 20% drop in line voltage. This drop is of short duration and could be reduced by using lowered voltage start up or a Wye-Delta start up technique, used by the DAF Indal machine. Detailed start up analysis is required but is not appropriate at this stage of preliminary feasibility. No serious start up problems were perceived which would affect the viability of the project.

Power Quality

Interfacing induction wind turbines with the existing diesel generator is unlikely to have any major impact on frequency, voltage or current quality.

Load Following Control

The diesel-wind turbine generator combination must have sufficient control response to adopt to changing wind speeds and wind turbine output. Provided wind turbine output is less than 20% of the load, a mechanical governor will be adequate to handle frequency changes. However, with wind turbine output at 50% or more of total load, and if electrical frequency for the community is critical, a more responsive electronic control may be required. Actual operation will define the frequency stability requirements more accurately. It should be mentioned that in the event of diesel generator or control system replacement, consideration should be given to specifying an electronic system in anticipation of wind turbine interfacing.

Site and Location Considerations

The anemometer is presently located on the top of a 200 metre hill, 0.7 km southeast of the community. Access is on foot (40 minutes) or by helicopter. The hill is well exposed to prevailing winds and is likely the best possible wind turbine location on the island. A potential alternative site exists closer to the village. This would be on the ridge of a lower hill, about 50 metres high, and 0.2 km south and west of the village, near the existing water storage tanks.

No wind data is available, however the cost of access and electrical transmission lines would be significantly reduced. Wind data should be measured at this alternative location and compared to the hilltop site.

Access

The hilltop location does not require road access. Equipment can be transported as required by helicopter for foundations, site work and power lines. Some erection work can be done by helicopter; the rest by manpower on the ground. The site is close enough to walk to for project personnel. The cost of a cat-track and four wheel drive vehicle access trail has been estimated to be $17,000/km and requires 1.5 to 2 km, assuming no gravelling or grading is necessary. For gravelling/grading the price increases by 50% to 100%. The access to the closer ridge should be evaluated for an alternative wind turbine site, in the next phase of the analysis.

Equipment Weight and Transport

All of the wind turbines selected have tilting tower and/or gin-pole erecting capabilities and do not require crane or helicopter erection. Components can be individually moved to the site, field connected and the assembly put in position.

Maintenance and Reliability

Vehicle access to the hilltop site would be desirable for transport of components and for maintenance. It is, however, not essential. The four turbines evaluated have demonstrated low maintenance and high reliability and additional evaluation should be made in the next phase.

5.2.7 Economic Analysis

Cost/Benefit Analysis

Results of the economic analysis are presented in Table 13 following.

TABLE 13

Wind Systems Cost, Savings and Electricity Cost Summary

	FLO-VAWT	DAF-VAWT		ESI-HAWT	ENERTECH-HAWT	
	100 kW	50 kW	2x50 kW	80 kW	45 kW	2x45 kW
Total Installed Cost $(1)	280,000	240,500	424,500	169,500	138,900	223,800
Annual Cost $	53,430	45,590	81,390	31,420	25,290	40,740
Annual Energy Production kWh	335,000	111,600	223,200	225,600	122,200	244,400
Diesel Fuel Savings $/year	44,900	14,950	29,910	30,230	16,370	32,750
Unit Cost $/kWh	.159	.41	.36	.139	.21	.167
$/kW Capacity	2,800	4,800	4,245	2,118	3,086	2,487

(1) The following cost data and assumptions were used in the preliminary analysis of wind turbine feasibility:

Wind Turbine Life	20 years
Depreciation	5% per year straight line
Operating Costs - Fixed	2% of total capital cost
- Variable	.7 mill/kWh
Interest	13%

Turbine costs were obtained from manufacturers.

Other costs are:

Freight	Ex Eastern USA	$ 4,000
Installation	50 kW - 1 only	$35,000
	- 2 @ 1.5	$52,500
	100 kW	$40,000
Electrical	.8 km @ $39,000/km	$40,000
	Fixed costs - $8,800	
	For 2 machines, add $5,000 to above	$45,000

The lowest per unit cost is available from the ESI-54 horizontal axis machine, at $ .14/kWh. Next are the FLO vertical axis 100 kW and two 45 kW Enertech horizontal axis at $ .16/kWh and $ .17/kWh respectively. Detailed results of output and unit cost of energy are provided as Appendix 4.

The present fuel displacement value of electricity is $ .4364/L divided by 3 kWh/L of fuel or $ .145/kWh. The fuel saved would be worth $30,230 per year for the ESI-54. It is therefore cost-effective to install a wind turbine such as the ESI-54 at this time, since it can produce electricity at less than the cost of fuel for the present generator.

A 50 kW VAWT, currently at Christopher Point, Vancouver Island, may be available for relocation to Kitkatla. This option is worth exploring in detail with B.C. Hydro and Power Authority, as it would significantly reduce the overall capital cost.

Sensitivity of Costs to Interest Rates

Reducing interest from 13% to 11.5% will reduce the annual cost for the ESI system from $31,420 to $28,870, and the unit cost of electricity from $ .14/kWh to $ .128/kWh. The capital intensity of the project and associated interest cost is responsible for 70% of the annual cost of the wind turbine.

5.3 Wood Energy

Rural B.C. residents presently utilize wood to a large extent for space heating. Over the past three years, Kitkatla residents have made a major change in heating fuel - over thirty families have recently switched from oil to wood as their primary heating fuel.

New homes planned for Kitkatla use either oil or wood as heating fuel. Of seven houses per year, four are wood heat while three are oil. The potential for wood heat has, to a large extent, already been realized. As furnace oil prices escalate, more homes will likely use wood, while additional existing and new homes will convert from oil to wood. The importance of wood as a heating fuel was shown in Section 3.5. Wood contributes between 25% and 27% of total non-commercial energy use, and displaces 74% to 81% of possible oil use for space heating.

A substantial wood resource exists and could be utilized for more than heating fuel. A small saw and planer mill, frequently found in many rural areas, should be explored as an alternative to purchasing dressed lumber. Cost savings and local employment would be the major benefits.

5.4 Solar Energy

Kitkatla is located on an island of relatively low relief. Compared to the coast, clouds do not accumulate to the same extent, giving Kitkatla greater solar radiation or insolation in winter, when compared to Prince Rupert or Kitimat. Temperatures at Bonilla Island are milder than coastal or inland locations, a result of being surrounded by water. Similarly, Kitkatla temperatures are not likely to be as extreme as coastal sites.

5.4.1 Contribution to Building Heat

From the house fuel use calculations, the solar energy contribution to heating was obtained. While this is often included as "internal gains," it provided a useful reference to show the existing contribution which solar energy makes to home heating.

The total solar contribution was calculated to be 694 GJ/year or 1160 GJ oil heat equivalent for all houses. Since curtains were closed part way, some shade from hills or trees occurred, an estimate was made that up to half the solar energy may not provide useful heat. When compared to the total demand for space heat of 4315 GJ, solar energy likely contributes between 8% and 16% of household space heating. The oil saved amounted to between 580 and 1160 GJ/year, a substantial amount when compared to the 1258 GJ of oil purchased for space heat.

5.4.2 Domestic Water Heaters

Technical Analysis

Computer simulations were performed for several solar domestic hot water systems. Different water use, collector areas and fuel types were assumed and a preliminary economic analysis made for several options of solar systems. Results of the computer analyses for energy savings are presented in Table 14, details are in Appendix 5.

Economic Analysis

Both two-collector and three-collector systems were evaluated for twenty year cash flow, for oil and electricity. For the purposes of analysis, solar system prices were obtained for Vancouver for materials and for installed prices. Assuming that a number of houses would be involved (i.e., twenty systems minimum), an additional 20% was added to installed cost in Vancouver for both collector systems - a price of $4200 in Kitkatla for a two-collector system; $5200 for a three-collector system.

Cumulative net present values of both systems for various water use and fuel types were derived as shown in Table 15. Details are contained in Appendix 5.

TABLE 14

Solar Water Heater Annual Savings - \$/year

	Two Collectors (4.04 m^2)		Three Collectors (6.06 m^2)	
Fuel Type	Oil(1)	Electricity(2)	Oil(1)	Electricity(2)
Household Water Use L/day				
140	93	218	N/A	N/A
C 140		231		
200	104	246	136	321
C 200	114	268		

(1) Oil provided by owner @ \$ .36/L with 55% annual efficiency (\$17.10/GJ) or electricity at \$ .06/kWL, i.e., homeowner cost.

(2) Electricity cost at 3 kWh/L, diesel fuel at .4364 or \$ .145/kWh. This is the real cost, to the community or diesel owner/operator, and is not based on sale price. This will be the cost to B.C. Hydro when they assume generation ownership, i.e., utility cost.

C "Conserver" - lower tank temperature, higher efficiency heat exchanger in solar system.

TABLE 15

Solar Water Heater Economic Analysis

Cumulative Net Present Value After Twenty Years, $

	Two Collectors (4.04 m^2)		Three Collectors (6.06 m^2)	
	Oil(1)	Electricity(2)	Oil(1)	Electricity(2)
Household Water Use L/day				
140	-2778	-50	N/A	N/A
200	-2522	554	-2972	1041

(1) Oil provided by owner @ $.[illegible]6/L with 55% annual efficiency ($17.10/GJ) or electricity at $ .06/kWL, i.e., homeowner cost.

(2) Electricity cost at 3 kWh/L, diesel fuel at .4364 or $ .145/kWh. This is the real cost, to the community or diesel owner/operator, and is not based on sale price. This will be the cost to B.C. Hydro when they assume generation ownership, i.e., utility cost.

Assumptions: Economic assumptions were interest at 12% per annum; discount rate of 10% per annum - the return from alternative investments, i.e., bank deposit; and a fuel inflation rate of 12% per annum. Analysis was run for a twenty year period, a reasonable estimate of the collector life.

Conclusions

From the analysis, it can be seen that there is no financial benefit presently available to the homeowner installing a commercially available solar water heater system, if he uses oil to heat water, or if he pays $ .06/kWh for electricity to heat water.

A financial benefit may exist, however, for the authority responsible for the generator. It may be to their benefit to avoid the high cost of diesel fuel by installing solar water heating systems. If generator fuel prices increase faster than 12% per annum as they have over the past ten years, financial benefit will be far greater than that represented here.

The potential for owner installed and "batch" solar water heaters, or other cost saving measures, should be explored, due to the substantial opportunity for local benefit and employment and long-term energy and dollar savings. Lower cost solar water heating systems may be economic at present.

Additional Solar Energy Systems

Future housing can be located with large south facing triple glazed windows to capture the sun's energy. If the houses are well insulated, on clear days almost all the heat required will be met by the sun. Passive solar designs will avoid overheating and maximize the use of the heat from the sun.

The potential for greenhouses and local agriculture is substantial although it is not culturally a tradition. Surrounded by water, Kitkatla has a relatively mild climate, while the distance from mainland mountains helps to increase available solar energy. Either low cost greenhouses or more substantial wind and storm resistant glasshouses could help provide fresh produce and local employment. Waste heat from the generator could provide some supplemental heat.

5.5 Small Scale Hydro

Several low head and medium head resources are located on nearby islands. Conventional small hydro could be utilized to provide electricity for Kitkatla, however underwater crossings of 1 to 2 km and land transmission of 4 to 15 km would be required. An initial map study of drainage area and a rainfall analysis was made for Billy Creek, to the north of Kitkatla on the south end of Porcher Island, and for the Scoular Lake/Kilpatrick Lake area on Pitt Island, to the east of Kitkatla (Figure 13).

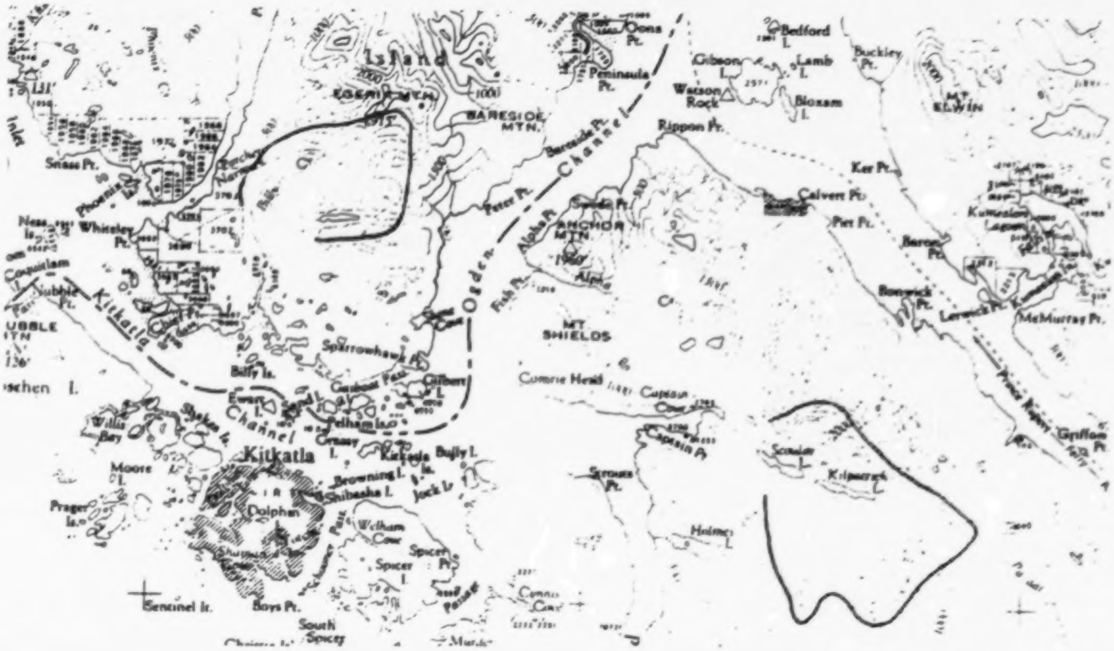

Island
EGERIA MTN.
BARESIDE MTN.
Oona Pt.
Peninsula Pt.
Bedford I.
Gibson I.
Lamb I.
Buckley Pt.
Watson Rock
Bloxam I.
MT. ELWIN
Rippon Pt.
Ker Pt.
Calvert Pt.
Pier Pt.
Kumealon Lagoon
Barrett Pt.
Snass Pt.
Phoenix
Whiteley Pt.
Ness Is.
Coquitlam
Stubble Pt.
Kitkatla
Peter Pt.
Alpha Pt.
ANCHOR MTN.
Ogden Channel
Fish Pt.
Sparrowhawk Pt.
MT. SHIELDS
Bonwick Pt.
Lewis Pt.
McMurray Pt.
Billy Is.
Gilbert
Gasboat Pass
Comrie Head
Captain Cove
Captain Pt.
Ewart
Pelham Is.
Kitkatla Channel
Willis Bay
Grassy I.
Kitkatla Is.
Bully I.
Moore I.
Browning I.
Shibasha I.
Jack Is.
Scoular L.
Kilpatrick
Griffon Pt.
Prince Rupert
Prager Is.
Dolphin
Stewart Pt.
Welham Cove
Spicer Pt.
Spicer I.
Holmes L.
Sentinel Is.
Boys Pt.
South Spicer
Connor Cove

Figure 13. Map Showing Small Hydro Electric Drainage Areas.

The Billy Creek area has an average estimated flow of $41 m^3/min$ (24 cfs) and an average potential of 285 kW. Average minimum summer available output is 113 kW, while maximum winter available energy is 500 kW (October). These values were calculated assuming rainfall was equal to Sandspit (or one-half of Prince Rupert) and a 61m (200 foot) head. A preliminary estimate for a 400 kW plant was made at \$3125/kW(1), or \$1.25 million, plus transmission - 7 km above water, 3 km below water at a cost of \$400,000. The preliminary cost estimate was \$1.65 million total.

The average output would be 285 kW. Over the year, the hydro plant would displace all of the diesel fuel presently used for electricity, valued at \$162,000 per year. Additional evaluation is recommended to refine rainfall and resource potential, and to more accurately evaluate costs and benefits. In the event that the diesel generator will be replaced, re-allocating funds to small scale hydro will lower actual costs and increase economic attractiveness. Appendix 6 shows monthly power figures developed.

An alternative drainage area, on Pitt Island, was evaluated. With a 50 foot head, average output was 140 kW, a maximum October value of 250 kW and a minimum output of 55 kW in July. The estimated cost was \$1.2 million, due to transmission distance. Diesel fuel savings were expected to be proportional to average capacity or about \$80,000 per year. This appears to be less attractive than the Billy Creek option, unless additional storage and head are obtained by a dam approximately 1 km from tidewater, where the valley narrows.

5.6 Grid Extension

A previous study of the feasibility of connecting Kitkatla to the B.C. Hydro grid determined that with several water crossings and land transmission of over 50 km, the cost would be approximately \$10 million (Acres, 1983).

---

(1) Present range of cost for remote locations is \$2500 - \$3500/kW.

5.7 Tidal Power

A number of opportunities exist for providing electricity to Kitkatla from tidal energy sources. Dolphin Lagoon occupies the west quarter of the island and is entered by a narrow channel. Because of high tides along the northcoast, rapid currents occur in the narrows. Unless the lagoon is rather deep in the centre and shallow at the entrance, it is not likely that the 60 hectare lagoon will provide sufficient volume or head to make a project cost-effective at this time (Figure 14).

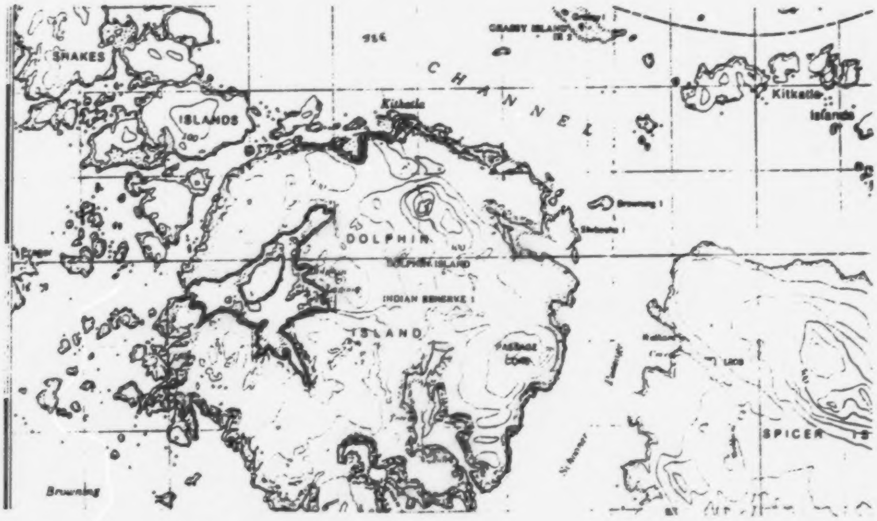

SNAKES
ISLANDS
100
CHANNEL
Kitkatla
Kitkatla
Islands
DOLPHIN
DOLPHIN ISLAND
INDIAN RESERVE 1
ISLAND
SPICER
Browning

Figure 14. Map Showing Dolphin Lagoon Tidal Basin.

Porcher Inlet, 2 km across Kitkatla Channel and a further 8 km north, has a narrows which also experiences strong currents due to tides. By comparison, it covers 20,000 hectares, over 300 times the area of Dolphin Lagoon (Figure 15). Technical results of B.C. Hydro's study of Massett Inlet on the Queen Charlotte Islands may apply to Porcher Narrows and the likely feasibility of tidal power. At this time, it is unlikely to be technically or economically feasible.

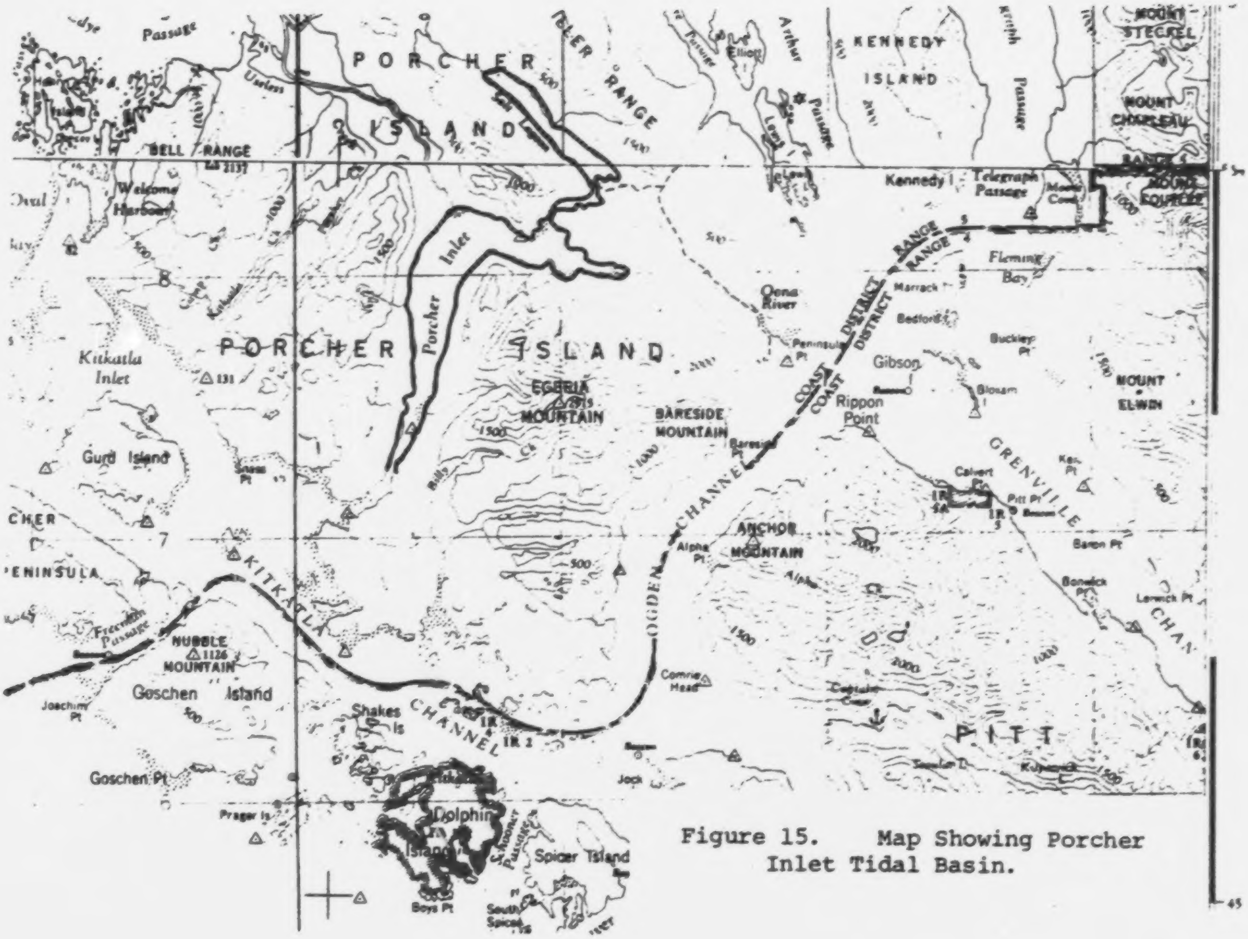

PORCHER ISLAND
Porcher Inlet
PORCHER ISLAND
EGERIA MOUNTAIN
BARESIDE MOUNTAIN
ANCHOR MOUNTAIN
KENNEDY ISLAND
Arthur Passage
Kennedy I
Telegraph Passage
MOUNT STECKEL
MOUNT CHAPLEAU
Fleming Bay
Marrack
Bedford
Oona River
Gibson
Rippon Point
Buckley Pt
Blossom
MOUNT ELWIN
GRENVILLE CHAN
Calvert
Pitt Pt
Baron Pt
Bonwick Pt
Lerwick Pt
COAST DISTRICT RANGE 5
COAST DISTRICT RANGE 4
OGDEN CHANNEL
Alpha Pt
Comrie Head
KITKATLA CHANNEL
Kitkatla Inlet
Gurd Island
BELL RANGE
Welcome Harbour
PENINSULA
Freeman Passage
HUBBLE MOUNTAIN
Goschen Island
Goschen Pt
Joachim Pt
Shakes Is
Dolphin Island
Spicer Island
Boys Pt
South Spicer
Prager Is
Jock
PITT

Figure 15. Map Showing Porcher Inlet Tidal Basin.

5.8 Compressed Natural Gas and Propane

Propane, or liquid petroleum gases, and compressed natural gas (CNG) offer opportunity to displace liquid fuels, especially diesel fuel for the generator. The present cost advantage would favour CNG at an estimated cost of $3.86/GJ versus diesel fuel at $10.50/GJ or propane at $15.30/GJ. The cost difference between diesel fuel and CNG would appear to offer some opportunity to implement storage and distribution facilities, particularly to the generator which presently consumes almost 400,000 L of diesel fuel annually, worth $160,000. If delivery of CNG cost 15% of retail at $3.86/GJ, the delivered cost would be

$4.40/GJ. At this price, the delivered CNG would cost $67,000, leaving a balance of $93,000 per year for facilities and transportation.

The school's use of 50,000 L of furnace oil, worth $18,000 per year, if replaced by CNG worth $8400, would enable an additional $9600 to be allocated toward such a system. While technically feasible, the economics are not likely to be favourable at the present time.

5.9 Other Fuels and Alternatives

5.9.1 Coal

Coal is unlikely to contribute to the energy needs of Kitkatla in the near future, principally because of transportation, storage, distribution, handling and coal appliance requirements. Wood is readily available at a lower cost.

5.9.2 Peat

Much of Dolphin Island has a substantial peat covering, however harvesting, drying, handling, combustion and ash disposal mean it also is unlikely to become a significant fuel source in the near future.

5.9.3 Propane and Butane

Propane and butane use will continue, however delivery and expense will likely limit the use of propane to cooking appliances and to perhaps a minor amount of space heat.

5.9.4 Biogas and Gasification

Both methods require substantial capital cost and ample feedstocks of organic materials. Neither conversion technique is likely to contribute to community energy needs in the near future.

5.9.5 Geothermal Resources and Wave Power

No geothermal resources exist in the area. Wave power along the southern and more exposed coastline may offer future opportunity as the technology and hardware become proven and reliable. Overland transmission lines would be needed, perhaps 6 km to 8 km.

6.0 ENERGY POLICY

6.1 Electrical Generation and Supply System

The present electrical system produces approximately 3 kWh for each litre of diesel fuel consumed. With diesel fuel costing $ .4034/L, the fuel cost of electricity is $ .134 per kilowatt hour.

The electricity is now sold to consumers at approximately $ .06 per kWh. A loss of almost $ .075/kWh occurs. It therefore is important to reduce electrical use wherever possible, using oil for furnaces or water heaters or, preferably, wood fuel. With a change to B.C. Hydro administration and operation, it is still important to minimize the cost of the generation and distribution of electricity. As long as costs exceed revenues, the deficit must be paid for by someone.

6.2 Energy and Housing Policy

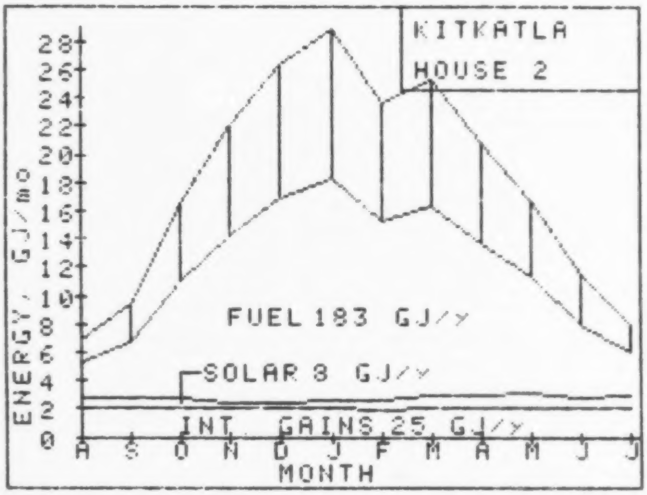
Housing policy does not presently address the opportunity to reduce energy consumption. At the design and construcion stages, small incremental costs can effect major energy savings. These savings will be cumulative as fuel costs escalate. Investigation of "low energy" packages as outlined in Section 4.3 is recommended.

REFERENCES

Sigma, 1983	"Energy Overview Study for Remote Communities in British Columbia," for Energy, Mines and Resources Canada, by Sigma Engineering, June 1983.
JBF Scientific, 1983	"Wind Energy Applications on Isolated Diesel Systems," for Canadian Electrical Association, by JBF Scientific Corp, 1983.
Spaceworks, 1983	"Kitkatla Civic Center Assessment," for Indian and Northern Affairs, by Spaceworks Architects, 1983.
ESL/IBI, 1981	"An Assessment of Wind Energy Exploitation in British Columbia," for Ministry of Energy, Mines and Petroleum Resources of British Columbia, 1981.
Acres, 1983	"Off-Oil Energy Generation and Conservation Opportunities for Remote Communities," for Indian and Northern Affairs and Energy, Mines and Resources Canada, by Acres Consulting Services, 1983.
SAR, 1977	"British Columbia Wind Resource; analysis of 100 AES data sites for wind power potential," Solar Applications and Research Ltd. (SAR), in house resource assessment, 1977.
NRC TM-WE-002	"Testing and Calibration of the DAF Indal Ltd. Wind Histogram," by P.J. Penna, Wind Energy Technical Memorandum, Low Speed Aerodynamics Laboratory, National Research Council of Canada, 1981.

APPENDIX 1 - HEAT AND ELECTRICAL USE CALCULATIONS

Heat Loss Calculations for Type 1 House

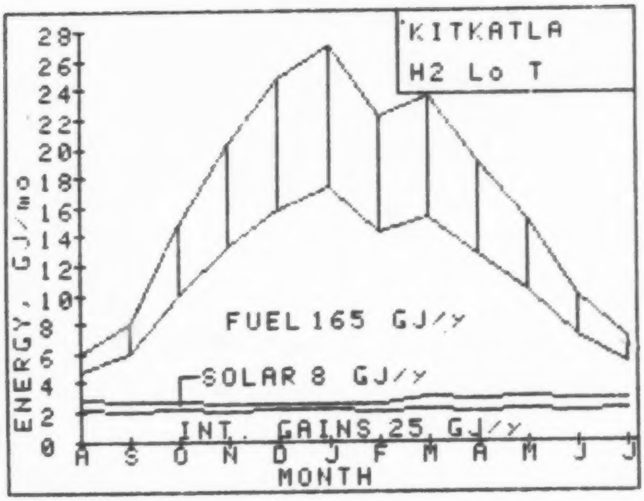


```
KITKATLA H2        (GJ)
MO LOAD INT  SOLAR DEMND  FUEL
A    5.3   2.1  0.8   2.4   4.0
S    6.7   2.0  0.7   4.0   6.6
O   11.0   2.1  0.6   8.3  13.8
N   14.2   2.0  0.5  11.7  19.5
D   16.9   2.1  0.4  14.4  23.9
J   18.3   2.1  0.5  15.7  26.2
F   15.3   1.9  0.6  12.7  21.2
M   16.3   2.1  0.9  13.4  22.3
A   13.7   2.0  0.9  10.7  17.9
M   11.3   2.1  1.0   8.2  13.7
J    8.0   2.0  0.8   5.2   8.6
J    5.9   2.1  0.8   3.0   5.0
 ---------------------------------
  143.    25.    8   110    183

COST (Fuel $ 9.40/GJ) $ 1717/yr
```

```
KITKATLA                         FILE
HOUSE 2                           KK
  Inside Temp,DAY       C         21
              NIGHT     C         18
  Loss Coeff.,DAY       W/C  391
              NIGHT     W/C  391
  Int. Gains, DAY       kW        .9
              NIGHT     kW        .7
  Mass Factor                     4
  Furnace size/Effic  kW 20 /.6
TYPE  AREA  NR.  AZ.  SLOPE  ABS.
DG     3.6   1    90    90   .9
DG     2.8   1   180    90   .9
DG     0     2   180    90   .95
DG     0     2   180    90   .9
DG     0     2   180    45   .8
```

Heat Loss Calculations for Type 1 House

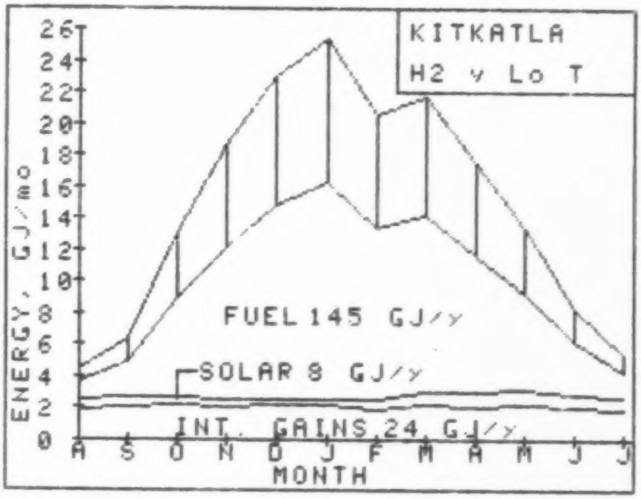


```
KITKATLA H2 Lo T        (GJ)
MO LOAD  INT.SOLAR DEMND  FUEL
A    4.8    2.1  0.7    1.9    3.2
S    5.9    2.0  0.7    3.2    5.3
O    9.9    2.1  0.6    7.2   12.1
N   13.2    2.0  0.4   10.7   17.8
D   15.8    2.1  0.4   13.3   22.2
J   17.3    2.1  0.5   14.7   24.5
F   14.3    1.9  0.6   11.8   19.7
M   15.3    2.1  0.8   12.3   20.5
A   12.7    2.0  0.9    9.7   16.2
M   10.3    2.1  1.0    7.2   12.0
J    7.2    2.0  0.8    4.3    7.1
J    5.3    2.1  0.8    2.4    4.0
   ------------------------------
   132.    25.    8.    99.   165.

COST (Fuel $ 9.40/GJ) $ 1547/yr
```

```
 KITKATLA                      FILE
 H2 Lo T                        KK
  Inside Temp.DAY      C       21
              NIGHT    C       16
  Loss Coeff.,DAY      W/C    391
              NIGHT    W/C    391
  Int. Gains, DAY      kW      .9
              NIGHT    kW      .7
  Mass Factor                   4
  Furnace size/Effic.kW 20 /.6
 TYPE AREA   NR.  AZ.  SLOPE ABS.
  DG     3.6  1     90    90   .9
  DG     2.8  1    180    90   .9
  DG     0    1      0     0   0
  DG     0    1      0     0   0
  DG     0    1      0     0   0
```

Heat Loss Calculations for Type 1 House

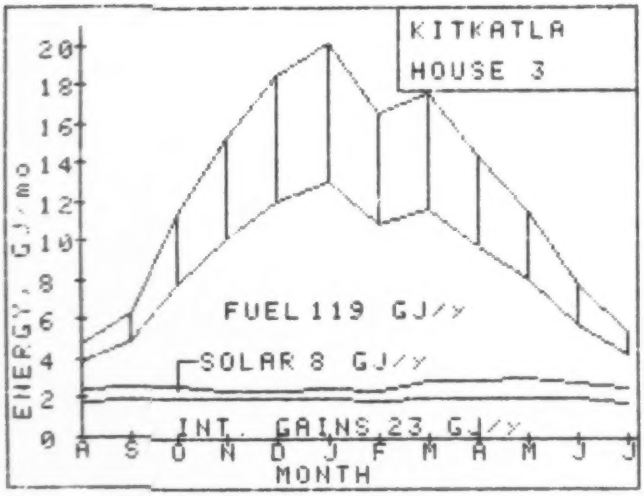


```
KITKATLA H2vLoT          (GJ)
MO LOAD INT.SOLAR DEMND  FUEL
A    3.7    1.8  0.7    1.2    2.0
S    4.9    2.0  0.7    2.2    3.6
O    8.9    2.1  0.6    6.2   10.3
N   12.2    2.0  0.4    9.7   16.1
D   14.8    2.1  0.4   12.3   20.5
J   16.2    2.1  0.5   13.7   22.8
F   13.4    1.9  0.6   10.8   18.1
M   14.2    2.1  0.8   11.3   18.8
A   11.7    2.0  0.9    8.7   14.5
M    9.2    2.1  1.0    6.1   10.2
J    6.1    2.0  0.8    3.3    5.5
J    4.3    1.9  0.7    1.6    2.7
  ------------------------------------
  120.    24.     8     87.   145.

COST (Fuel $ 9.40/GJ) $ 1364/yr
```

```
KITKATLA                       FILE
H2 v Lo T                       KK
 Inside Temp,DAY       C        19
             NIGHT     C        16
 Loss Coeff.,DAY       W/C     391
             NIGHT     W/C     391
 Int. Gains, DAY       kW       .9
             NIGHT     kW       .7
 Mass Factor                     4
 Furnace size/Effic.kW 20 /.6
TYPE AREA   NR.  AZ.  SLOPE  ABS.
 DG     3.6  1     90    90   .9
 DG     2.8  1    180    90   .9
 DG     0    1      0     0   0
 DG     0    1      0     0   0
 DG     0    1      0     0   0
```

Heat Loss Calculations for Type 2 House

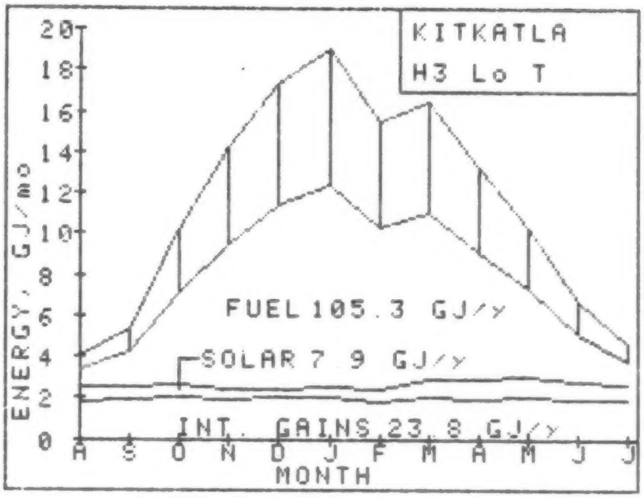


```
KITKATLA H3        (GJ)
MO LOAD  INT.SOLAR DEMND   FUEL
A    3.8    1.7   0.7    1.4    2.3
S    4.8    1.9   0 7    2 2    3 7
O    7.9    2.0   0.6    5.3    8.8
N   10.2    2.0   0 4    7.8   13.0
D   12.1    2.0   0 4    9 7   16 2
J   13.2    2.0   0.5   10.6   17 7
F   11.0    1.9   0.6    8.5   14.2
M   11.7    2.0   0 8    8.9   14 8
A    9.8    2.0   0.9    7.0   11 6
M    8.1    2.0   1 0    5.1    8 5
J    5.8    2 0   0.8    3.0    5 0
J    4.3    1.8   0.8    1.7    2 9
   ---------------------------------
   103.     23.     8.     71    119

COST (Fuel $ 9.40/GJ) $ 1115/yr
```

```
KITKATLA                        FILE
HOUSE 3                           KK
  Inside Temp,DAY       C         21
              NIGHT     C         18
  Loss Coeff.,DAY       W/C      281
              NIGHT     W/C      281
  Int. Gains, DAY       kW        .9
              NIGHT     kW        .7
  Mass Factor                     4
  Furnace size/Effic.kW 20 /.6
TYPE AREA   NR.  AZ.  SLOPE ABS.
 DG     3.6  1     90    90   .9
 DG     2.8  1    180    90   .9
 DG     0    2    180    90   .95
 DG     0    2    180    90   .9
 DG     0    2    180    45   .8
```

Heat Loss Calculations for Type 2 House

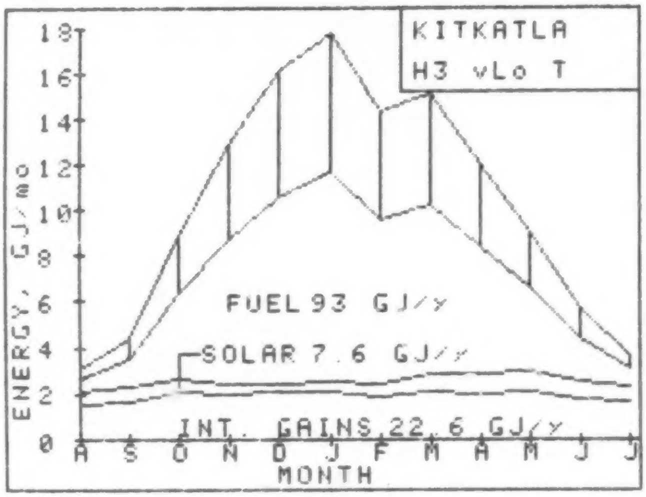


```
KITKATLA H3 Lo T        (GJ)
MO LOAD INT.SOLAR DEMND  FUEL
A    3.4    1.9  0.6    0.9    1.5
S    4.2    2.0  0.6    1.7    2.8
O    7.2    2.0  0.6    4.5    7.6
N    9.5    2.0  0.4    7.1   11.9
D   11.4    2.0  0.4    9.0   14.9
J   12.4    2.0  0.5    9.9   16.5
F   10.3    1.9  0.6    7.8   13.1
M   11.0    2.0  0.8    8.1   13.5
A    9.1    2.0  0.9    6.3   10.4
M    7.4    2.0  0.9    4.4    7.3
J    5.1    2.0  0.8    2.4    4.0
J    3.8    1.9  0.7    1.2    2.0
   ------------------------------
   94.8 23.7   7.8   63.2 105.4

COST (Fuel $ 9.40/GJ) $  990/yr
```

```
KITKATLA                       FILE
HOUSE 3 Lo T                    KK
  Inside Temp,DAY       C       21
              NIGHT     C       16
  Loss Coeff.,DAY       W/C    281
              NIGHT     W/C    281
  Int. Gains, DAY       kW      .9
              NIGHT     kW      .7
  Mass Factor                   4
  Furnace size/Effic.kW 20 /.6
TYPE AREA  NR.  AZ.  SLOPE ABS.
 DG    3.6  1    90    90   .9
 DG    2.8  1   180    90   .9
 DG    0    1     0     0   0
 DG    0    1     0     0   0
 DG    0    1     0     0   0
```

Heat Loss Calculations for Type 2 House

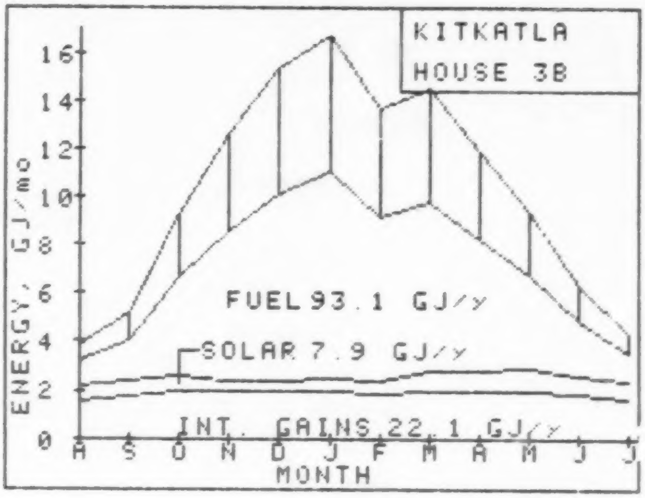


```
KITKATLA H3 vLo T          (GJ)
MO LOAD  INT SOLAR DEMND  FUEL
A    2.7    1.5  0.6    0.5   0 9
S    3.5    1.7  0.6    1.2   2.1
O    6.4    2.0  0.6    3.8   6.3
N    8.7    2.0  0.4    6.4  10 6
D   10.6    2.0  0 4    8.2  13.7
J   11.7    2.0  0.5    9.2  15.3
F    9.6    1.9  0 6    7.2  12.0
M   10.2    2.0  0.8    7 4  12.3
A    8.4    2.0  0 9    5.5   9.2
M    6.6    2.0  0.9    3.7   6 1
J    4.4    1.8  0.7    1.9   3.1
J    3.1    1.6  0.7    0.8   1 3
  --------------------------------
   85.9 22.6   7.6   55.8   92.9

COST (Fuel $ 9.40/GJ) $  874/yr
```

```
KITKATLA                      FILE
HOUSE 3 v Lo T                 KK
  Inside Temp,DAY       C      19
              NIGHT     C      16
  Loss Coeff.,DAY       W/C   281
              NIGHT     W/C   281
  Int. Gains, DAY       kW     .9
              NIGHT     kW     .7
  Mass Factor                  4
  Furnace size/Effic.kW 20 /.6
TYPE  AREA   NR.  AZ.  SLOPE  ABS.
 DG    3.6   1     90    90    .9
 DG    2.8   1    180    90    .9
 DG    0     1      0     0    0
 DG    0     1      0     0    0
 DG    0     1      0     0    0
```

Heat Loss Calculations for Type 3 House

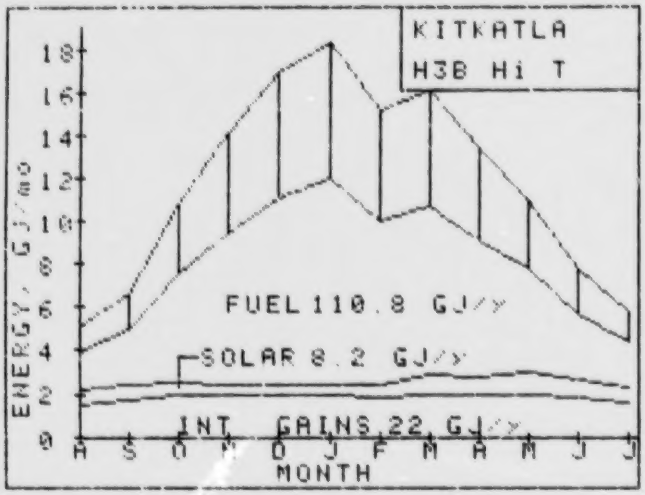


```
KITKATLA HOUSE 3B       (GJ)
MO LOAD  INT  SOLAR DEMND  FUEL
A    3.2   1.5  0.7    1.0    1.6
S    4.0   1.7  0.6    1.7    2.9
O    6.6   2.0  0.6    4.1    6.8
N    8.5   1.9  0.4    6.2   10.3
D   10.1   2.0  0.4    7.8   13.0
J   11.0   2.0  0.5    8.5   14.3
F    9.2   1.8  0.6    6.8   11.3
M    9.8   2.0  0.8    7.0   11.7
A    8.2   1.9  0.9    5.4    9.1
M    6.8   2.0  0.9    3.9    6.5
J    4.8   1.8  0.8    2.2    3.7
J    3.6   1.6  0.7    1.2    2.1
   ------------------------------
   85.9 22.2   7.9   55.9   93.1

COST (Fuel $ 9.40/GJ) $  875/yr
```

```
KITKATLA                         FILE
HOUSE 3B                          kK
 Inside Temp.DAY       C        21
             NIGHT     C        18
 Loss Coeff.,DAY       W/C     235
             NIGHT     W/C     235
 Int. Gains, DAY       kW       .9
             NIGHT     kW       .7
 Mass Factor                     4
 Furnace size/Effic.kW 20 /.6
TYPE AREA   NR.  AZ.  SLOPE ABS
 DG     3.6  1     90    90   .9
 DG     2.8  1    180    90   .9
 DG     0    1      0     0   0
 DG     0    1      0     0   0
 DG     0    1      0     0   0
```

Heat Loss Calculations for Type 3 House

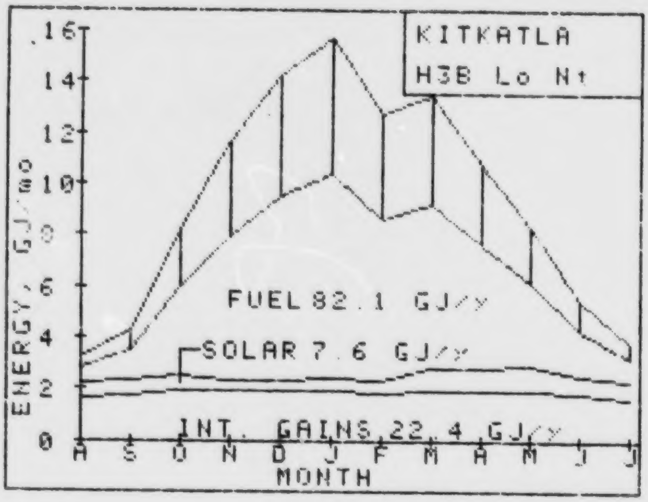


```
KITKATLA H3E HiT        (GJ)
MO LOAD  INT.SOLAR DEMND  FUEL
A    4.0   1.5  0.7   1.8    3.0
S    4.9   1.7  0.7   2.6    4.3
O    7.6   2.0  0.6   5.0    8.3
N    9.4   1.9  0.5   7.1   11.8
D   11.1   2.0  0.4   8.7   14.5
J   12.0   2.0  0.5   9.5   15.8
F   10.0   1.8  0.6   7.6   12.7
M   10.8   2.0  0.9   7.9   13.2
A    9.1   1.9  0.9   6.3   10.5
M    7.7   2.0  1.0   4.8    8.0
J    5.7   1.8  0.8   3.1    5.2
J    4.4   1.6  0.8   2.1    3.5
  -------------------------------
  96.7 22.0   8.3   66.4 110.7

COST (Fuel $ 9.40/GJ) $ 1041/yr
```

```
 KITKATLA                        FILE
 HOUSE 3B Hi T                     KK
   Inside Temp.,DAY      C         21
                NIGHT    C         21
   Loss Coeff.,DAY       W/C      235
                NIGHT    W/C      235
   Int. Gains, DAY       kW        .9
                NIGHT    kW        .7
   Mass Factor                      4
   Furnace size/Effic.kW 20 /.6
 TYPE AREA   NR.  AZ.  SLOPE ABS.
   DG    3.6  1     90    90   .9
   DG    2.8  1    180    90   .9
   DG    0    1      0     0   0
   DG    0    1      0     0   0
   DG    0    1      0     0   0
```

Heat Loss Calculations for Type 3 House

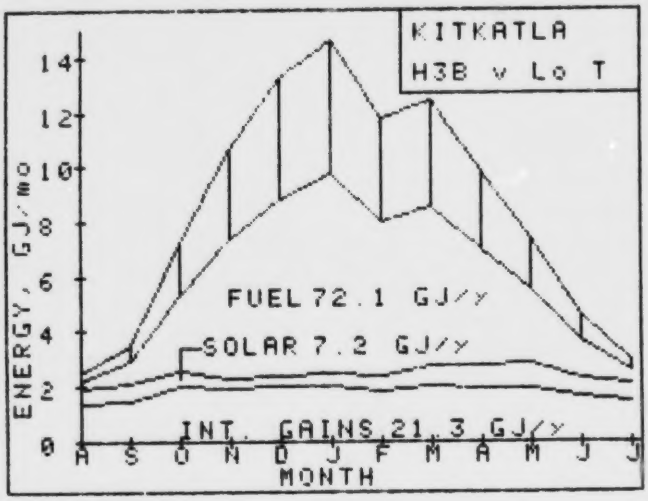


```
KITKATLA H3B LoN        (GJ)
MO LOAD  INT SOLAR  DEMND  FUEL
A    2.9   1.6  0.6    0.6    1.0
S    3.5   1.8  0.6    1.2    2.0
O    6.0   2.0  0.6    3.4    5.7
N    7.9   1.9  0.4    5.6    9.3
D    9.5   2.0  0.4    7.2   11.9
J   10.4   2.0  0.5    7.9   13.2
F    8.6   1.8  0.6    6.2   10.4
M    9.2   2.0  0.8    6.4   10.7
A    7.6   1.9  0.9    4.9    8.1
M    6.2   2.0  0.9    3.3    5.4
J    4.3   1.8  0.7    1.7    2.9
J    3.2   1.7  0.7    0.8    1.4
  -------------------------------
   79.3 22.4   7.6   49.3   82.1

COST (Fuel $ 9.40/GJ) $  772/yr
```

```
KITKATLA                          FILE
HOUSE 3B Lo N                       KK
  Inside Temp,DAY        C         21
              NIGHT      C         16
  Loss Coeff.,DAY        W/C      235
              NIGHT      W/C      235
  Int. Gains, DAY        kW        .9
              NIGHT      kW        .7
  Mass Factor                       4
  Furnace size/Effic.kW 20 /.6
TYPE AREA  NR.  AZ.  SLOPE ABS.
 DG     3.6  1     90    90   .9
 DG     2.8  1    180    90   .9
 DG     0    1      0     0   0
 DG     0    1      0     0   0
 DG     0    1      0     0   0
```

Heat Loss Calculations for Type 3 House

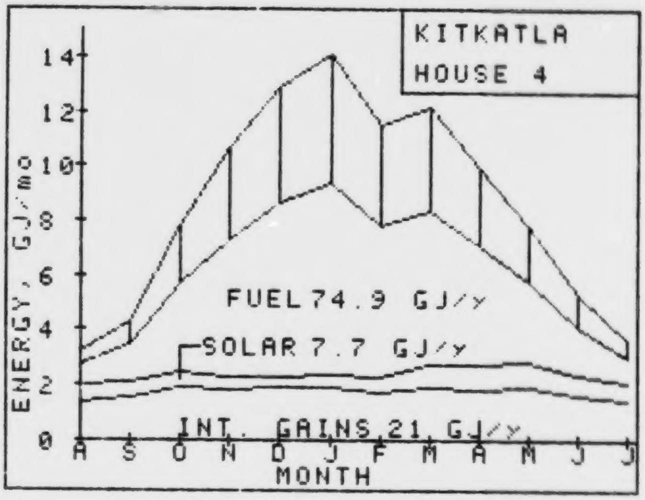


```
KITKATLA H3BVLoT        (GJ)
MO LOAD  INT.SOLAR DEMND  FUEL
A    2.2   1.4  0.5   0.3   0.5
S    2.9   1.5  0.6   0.9   1.5
O    5.4   2.0  0.5   2.8   4.7
N    7.3   1.9  0.4   5.0   8.3
D    8.9   2.0  0.3   6.5  10.9
J    9.8   2.0  0.4   7.3  12.2
F    8.0   1.8  0.6   5.7   9.4
M    8.6   2.0  0.8   5.8   9.6
A    7.0   1.9  0.8   4.2   7.1
M    5.5   1.9  0.9   2.7   4.6
J    3.7   1.6  0.7   1.4   2.3
J    2.6   1.4  0.6   0.5   0.9
   ---------------------------
   71.8 21.3  7.3  43.3  72.1

COST (Fuel $ 9.40/GJ) $  678/yr
```

```
KITKATLA                   FILE
H3B v Lo T                  KK
 Inside Temp,DAY     C      19
             NIGHT   C      16
 Loss Coeff.,DAY     W/C   235
             NIGHT   W/C   235
 Int. Gains, DAY     kW     .9
             NIGHT   kW     .7
 Mass Factor                4
 Furnace size/Effic.kW 20 /.6
TYPE AREA  NR.  AZ.  SLOPE ABS.
 DG    3.6  1    90    90   .9
 DG    2.8  1   180    90   .9
 DG    0    1     0     0   0
 DG    0    1     0     0   0
 DG    0    1     0     0   0
```

Heat Loss Calculations for Type 4a House

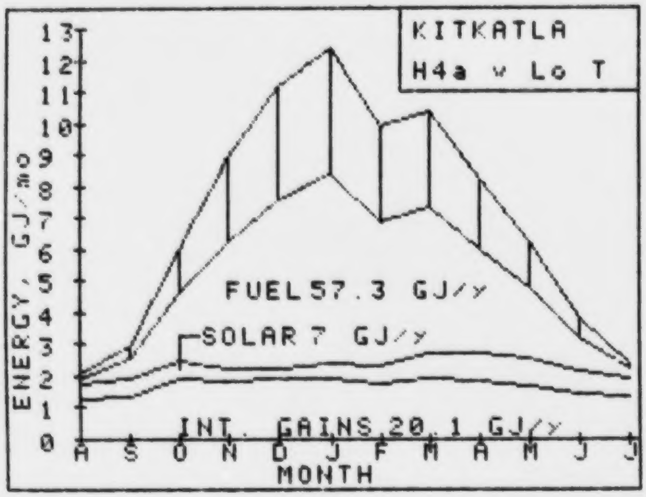


```
KITKATLA HOUSE 4        (GJ)
MO LOAD INT.SOLAR DEMND  FUEL
A   2.7    1.4  0.6    0.7   1.2
S   3.5    1.5  0.6    1.3   2.2
O   5.7    1.9  0.6    3.2   5.3
N   7.3    1.9  0.4    5.0   8.4
D   8.7    1.9  0.4    6.4  10.6
J   9.4    1.9  0.5    7.0  11.7
F   7.8    1.7  0.6    5.5   9.2
M   8.4    1.9  0.8    5.7   9.4
A   7.0    1.9  0.9    4.3   7.2
M   5.8    1.9  0.9    3.0   5.0
J   4.1    1.6  0.7    1.8   3.0
J   3.1    1.4  0.7    0.9   1.5
 ------------------------------
  73.5 20.9  7.6  44.9  74.8

COST (Fuel $ 9.40/GJ) $  703/yr
```

```
KITTKATLA                    FILE
HOUSE 4                       KK
 Inside Temp,DAY      C      21
             NIGHT    C      18
 Loss Coeff.,DAY      W/C   201
             NIGHT    W/C   201
 Int. Gains, DAY      kW     .9
             NIGHT    kW     .7
 Mass Factor                 4
 Furnace size/Effic.kW 20 /.6
TYPE AREA  NR.  AZ.  SLOPE ABS.
 DG   3.6   1    90    90   .9
 DG   2.8   1   180    90   .9
 DG   0     1     0     0   0
 DG   0     1     0     0   0
 DG   0     1     0     0   0
```

Heat Loss Calculations for Type 4a House

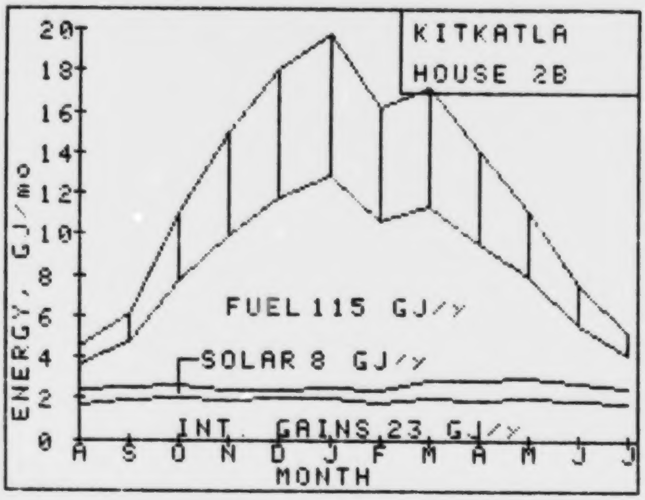


```
KITKATLA H4a vLo T          (GJ)
MO LOAD  INT.SOLAR DEMND   FUEL
A   1.9   1.2  0.5   0.2    0.3
S   2.5   1.3  0.5   0.6    1 1
O   4.6   1.9  0.5   2.1    3.6
N   6.3   1.9  0 4   4.0    6.7
D   7.6   1.9  0.3   5.3    8.9
J   8.3   1.9  0 4   6.0   10 0
F   6.9   1.7  0.5   4.6    7.6
M   7.3   1.9  0.8   4.6    7.7
A   6.0   1.8  0.8   3 3    5 5
M   4.7   1.7  0.9   2.2    3.7
J   3.2   1.4  0.7   1.0    1.7
J   2.2   1.4  0.5   0.3    0.5
  ------------------------------
   61.5 20.1  6.9  34.4   57 3

COST (Fuel $ 9.40/GJ) $  539/yr
```

```
KITKATLA                     FILE
HOUSE 4a v Lo T               KK
  Inside Temp,DAY     C      19
              NIGHT   C      16
  Loss Coeff.,DAY     W/C   201
              NIGHT   W/C   201
  Int. Gains, DAY     kW     .9
              NIGHT   kW     .7
  Mass Factor                4
  Furnace size/Effic.kW 20 /.6
TYPE AREA   NR.  AZ.  SLOPE ABS.
 DG    3.6   1    90    90   .9
 DG    2.8   1   180    90   .9
 DG    0     1     0     0   0
 DG    0     1     0     0   0
 DG    0     1     0     0   0
```

Heat Loss Calculations for Type 4b House

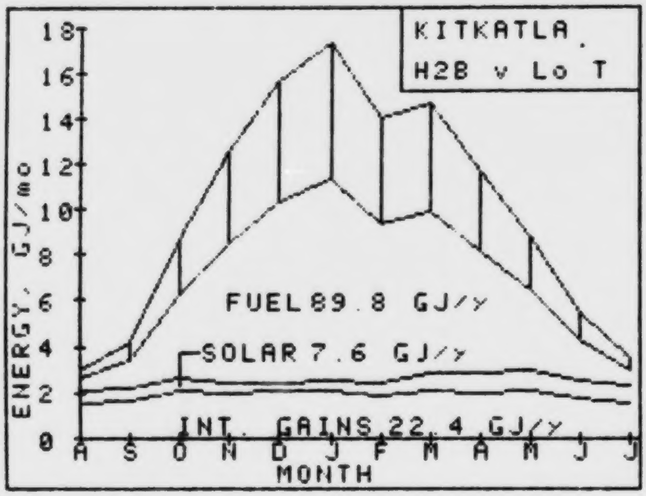


```
KITKATLA HOUSE 2B        (GJ)
MO LOAD  INT SOLAR DEMND  FUEL
A    3.7   1.7  0 7    1 3   2.2
S    4.7   1.9  0 7    2.2   3 6
O    7.7   2.0  0 6    5.1   8 5
N    9.9   2.0  0.4    7.5  12.6
D   11.8   2.0  0.4    9.4  15 7
J   12.8   2.0  0.5   10.3  17.2
F   10.7   1.9  0 6    8.3  13.8
M   11.4   2.0  0.8    8.6  14.3
A    9.6   2.0  0.9    6.7  11 2
M    7.9   2.0  1.0    4.9   9.2
J    5.6   2.0  0.8    2.9   4.8
J    4.2   1.8  0 8    1.6   2 7
  ---------------------------------
  100.     23.    8.    69.  115.

COST (Fuel $ 9.40/GJ) $ 1078/yr
```

```
KITKATLA                      FILE
HOUSE 2B                       KK
 Inside Temp,DAY      C       21
             NIGHT    C       18
 Loss Coeff.,DAY      W/C    274
             NIGHT    W/C    274
 Int. Gains, DAY      kW       .
             NIGHT    kW
 Mass Factor                   4
 Furnace size/Effic.kW 20 /.6
TYPE AREA  NR.  AZ.  SLOPE  ABS.
 DG    3.6  1     90    90   .9
 DG    2.8  1    180    90   .9
 DG    0    1      0     0   0
 DG    0    1      0     0   0
 DG    0    1      0     0   0
```

Heat Loss Calculations for Type 4b House

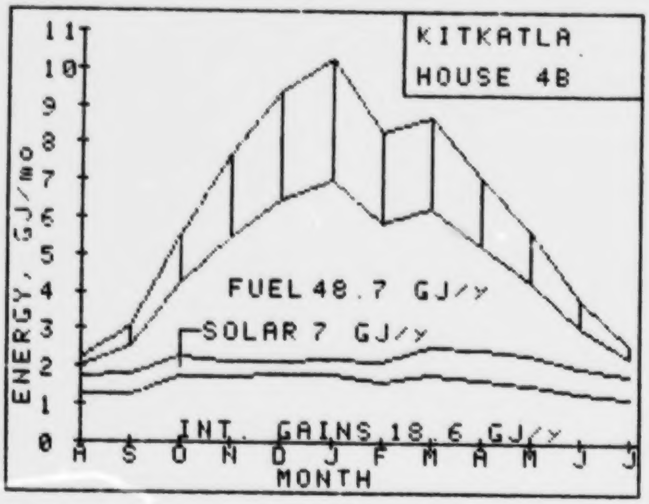


```
KITKATLA H2B vLoT         (GJ)
MO LOAD  INT.SOLAR DEMND   FUEL
A    2.6    1.5  0.6    0.5    0.8
S    3.4    1.6  0.6    1.2    2.0
O    6.2    2.0  0.6    3.6    6.1
N    8.5    2.0  0.4    6.1   10.2
D   10.3    2.0  0.4    8.0   13.3
J   11.4    2.0  0.5    8.9   14.8
F    9.4    1.9  0.6    6.9   11.6
M   10.0    2.0  0.8    7.1   11.9
A    8.2    2.0  0.9    5.3    8.9
M    6.5    2.0  0.9    3.5    5.8
J    4.3    1.8  0.7    1.8    3.0
J    3.0    1.6  0.7    0.8    1.3
  ------------------------------
   83.8 22.4   7.5   53.8   89.7

COST (Fuel $ 9.40/GJ) $  843/yr
```

```
KITKATLA                    FILE
HOUSE 2B v Lo T               KK
 Inside Temp,DAY     C      19
             NIGHT   C      16
 Loss Coeff.,DAY     W/C   274
             NIGHT   W/C   274
 Int. Gains, DAY     kW     .9
             NIGHT   kW     .7
 Mass Factor                 4
 Furnace size/Effic.kW 20 /.6
TYPE AREA  NR.  AZ.  SLOPE ABS.
 DG     3.6  1    90    90   .9
 DG     2.8  1   180    90   .9
 DG     0    1     0     0   0
 DG     0    1     0     0   0
 DG     0    1     0     0   0
```

Heat Loss Calculations for Type 5 House

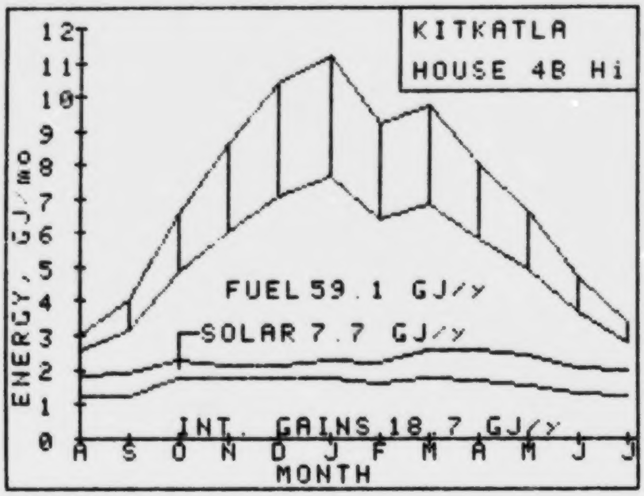


```
KITKATLA HOUSE 4E        (GJ)
MO LOAD  INT.SOLAR DEMND  FUEL
A   2.0   1.2  0.5   0.3   0.5
S   2.6   1.2  0.6   0.8   1.3
O   4.2   1.7  0.5   2.0   3.3
N   5.4   1.7  0.4   3.3   5.5
D   6.5   1.8  0.3   4.7   7.2
J   7.0   1.8  0.4   4.9   9.0
F   5.9   1.6  0.6   3.7   5.1
M   6.3   1.8  0.8   3.7   5.2
A   5.2   1.7  0.8   2.7   4.6
M   4.3   1.5  0.9   2.0   3.3
J   3.1   1.3  0.7   1.1   1.8
J   2.3   1.2  0.6   0.5   0.8
  ------------------------------
   54.8 18.6  7.1   29.2  48.6

COST (Fuel $ 9.40/GJ) $  457/yr
```

```
 KITKATLA                     FILE
 HOUSE 4B                      KK
  Inside Temp,DAY      C       21
              NIGHT    C       18
  Loss Coeff.,DAY      W/C    150
              NIGHT    W/C    150
  Int. Gains, DAY      kW      .9
              NIGHT    kW      .7
  Mass Factor                  4
  Furnace size/Effic.kW 20 /.6
 TYPE AREA  NR. AZ.  SLOPE ABS.
 DG    3.6   1    90   90   .9
 DG    2.8   1   180   90   .9
 DG    0     1     0    0   0
 DG    0     1     0    0   0
 DG    0     1     0    0   0
```

Heat Loss Calculations for Type 5 House



```
KITKATLA HOUSE4BHi         (GJ)
MO LOAD  INT.SOLAR DEMND   FUEL
A   2.5   1.2  0.6   0.7    1.2
S   3.1   1.2  0.6   1.3    2.1
O   4.8   1.7  0.6   2.5    4.2
N   6.0   1.7  0.4   3.9    6.5
D   7.1   1.8  0.4   4.9    8.2
J   7.6   1.8  0.5   5.4    9.0
F   6.4   1.6  0.6   4.2    7.0
M   6.9   1.8  0.8   4.3    7.1
A   5.8   1.7  0.8   3.3    5.5
M   4.9   1.5  0.9   2.5    4.2
J   3.7   1.3  0.7   1.6    2.7
J   2.8   1.3  0.7   0.9    1.5
  ------------------------------
   61.8 18.6  7.6  35.5   59.2

COST (Fuel $ 9.40/GJ) $  556/yr
```

```
 KITKATLA                     FILE
 HOUSE 4B Hi                    KK
   Inside Temp,DAY     C       21
               NIGHT   C       21
   Loss Coeff.,DAY     W/C    150
               NIGHT   W/C    150
   Int. Gains, DAY     kW      .9
               NIGHT   kW      .7
   Mass Factor                  4
   Furnace size/Effic.kW 20 /.6
 TYPE AREA  NR. AZ.  SLOPE ABS.
  DG    3.6  1    90    90   .9
  DG    2.8  1   180    90   .9
  DG    0    1     0     0   0
  DG    0    1     0     0   0
  DG    0    1     0     0   0
```

Appendix 1.2 - Kitkatla Electrical Use Assumptions

Residential Use	kWh/month	
Freezer	120	
Refrigerator	120	
Television	40	
Lights	120	
Small Appliances	25	
Kettle	33	
Washer	6	
	464	(no water heater)

Annual Use = 97 houses x 464 kWh/month
x 12 months = 540,100 kWh/year

Additional Residential Use
Freezers and Dryers = 39,000 kWh/year
Water Heaters - 20 total = 129,600 kWh/year

Total Residential Use = 708,700 kWh/year

School Use

Secondary/Elementary

Lights	
- main floor	8.8 kW
- upper floor	9.7 kW
Subtotal	18.5 kW

Annual Use = 18.5 kW
x 37.5 hours/week
x 41 weeks = 28,400 kWh/year
Equipment and Miscellaneous at 20% = 5,700 kWh/year

Primary School
Two at 1/3 of large school
(including equipment
and miscellaneous) = 11,000 kWh/year

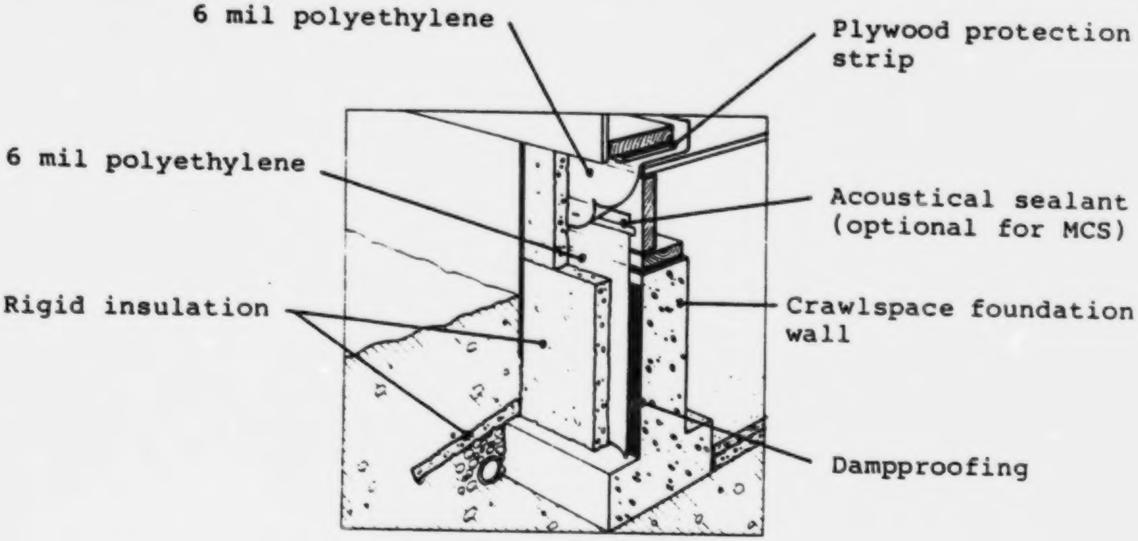
Total School Use = 45,100 kWh/year

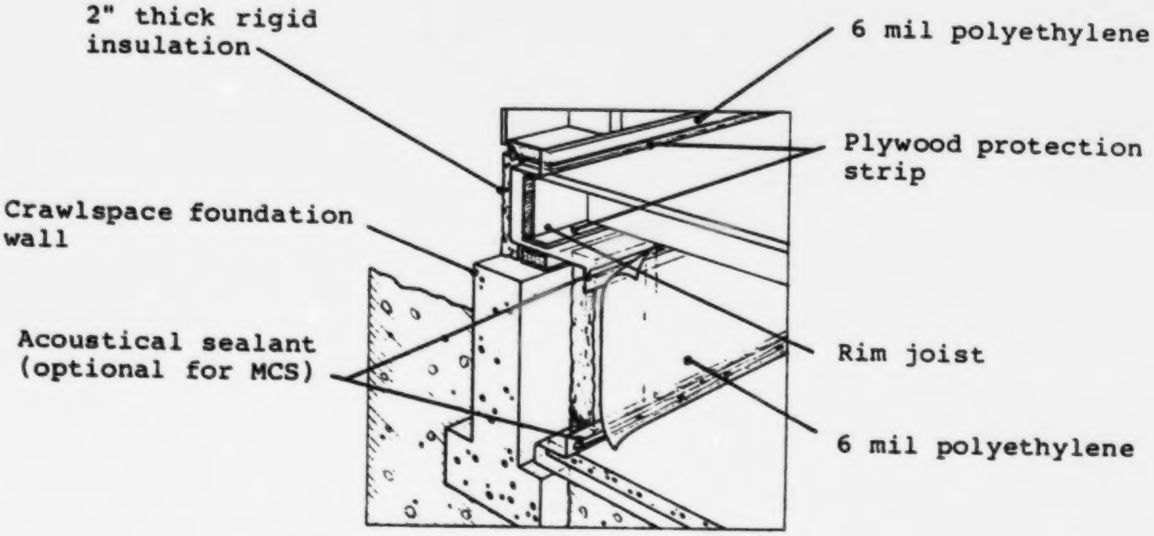
Appendix 1.2

Teacherages	
Seven x "average B.C. use" at 10,000 kWh/year (includes electric water heater)	= 70,000 kWh/year
Clinic	
Equivalent to 2 Kitkatla residences	= 11,100 kWh/year
Band Office	
Equivalent to 1.5 Kitkatla residences	= 8,400 kWh/year
Churches	
Two each	
Equivalent to "average B.C. household use" (excludes water heater)	= 13,200 kWh/year
Stores	
Add 3 "average B.C. use" house equivalents	= 30,000 kWh/year
Water System	= 11,500 kWh/year
Street Lights	= 26,300 kWh/year
Sewage System	= 3,800 kWh/year
Total Estimated Annual Electrical Demand	928,100 kWh/year
or 928,100/278 = 3338 GJ/year	

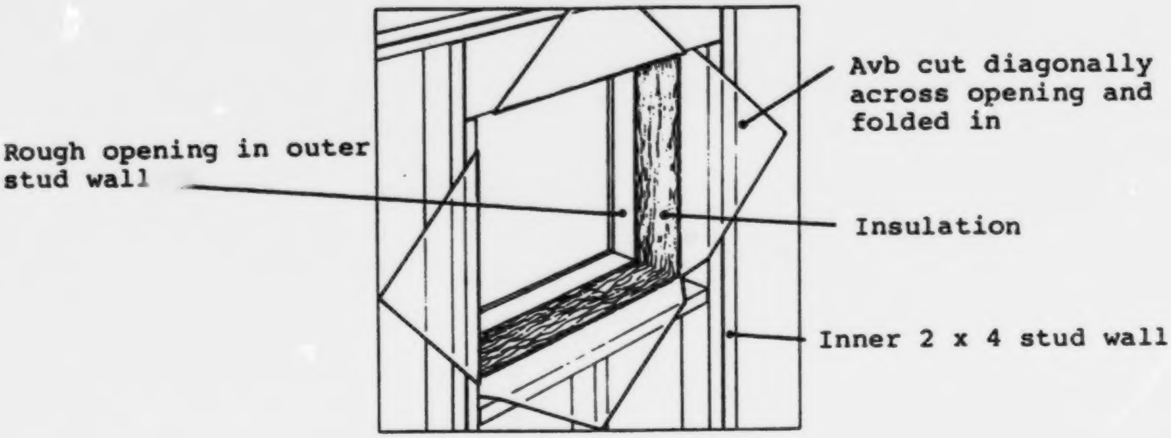
APPENDIX 2 - NEW HOUSING DESIGN DETAILS FOR ENERGY EFFICIENCY

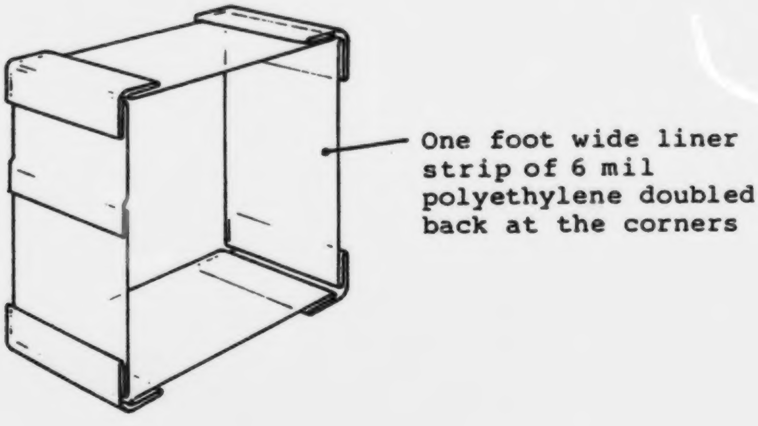
New Housing Design Details for Energy Efficiency
Air Sealing at Foundations

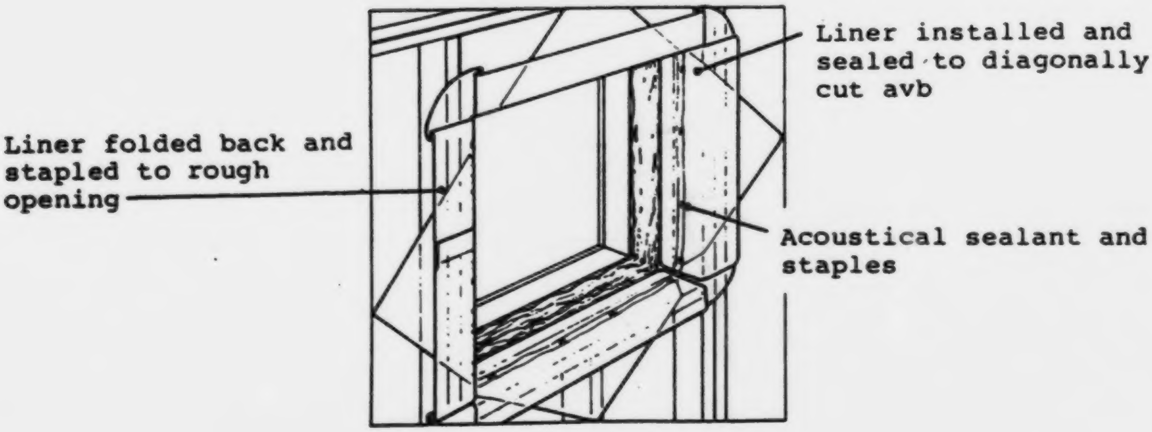

6 mil polyethylene
Plywood protection strip
6 mil polyethylene
Acoustical sealant (optional for MCS)
Rigid insulation
Crawlspace foundation wall
Dampproofing


2" thick rigid insulation
6 mil polyethylene
Plywood protection strip
Crawlspace foundation wall
Acoustical sealant (optional for MCS)
Rim joist
6 mil polyethylene

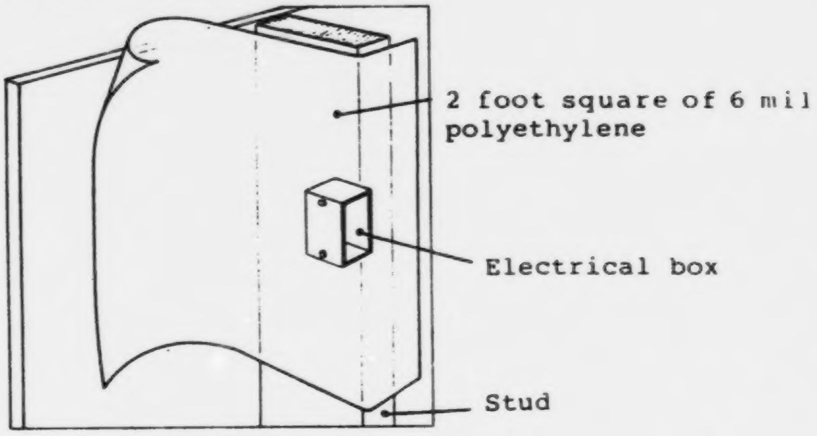
New Housing Design Details for Energy Efficiency
Air Sealing at Windows and Doors

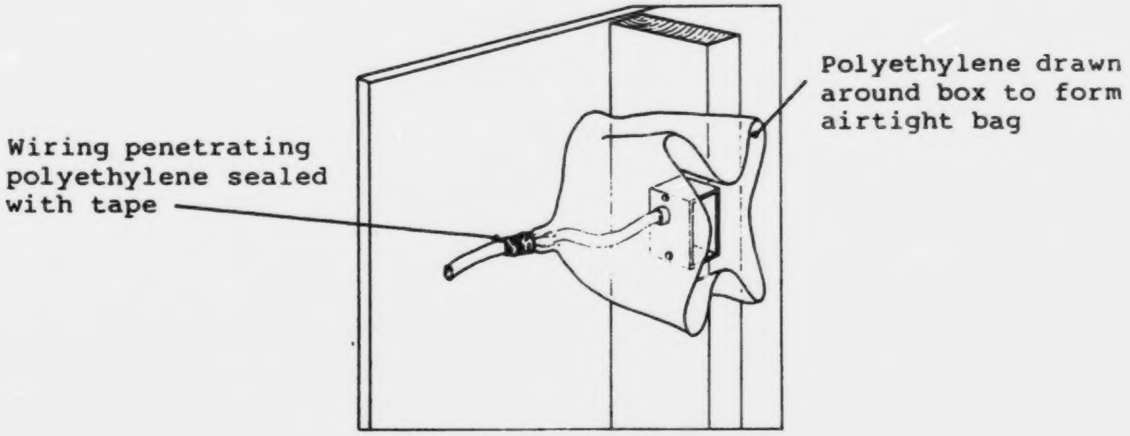

Avb cut diagonally across opening and folded in
Rough opening in outer stud wall
Insulation
Inner 2 x 4 stud wall

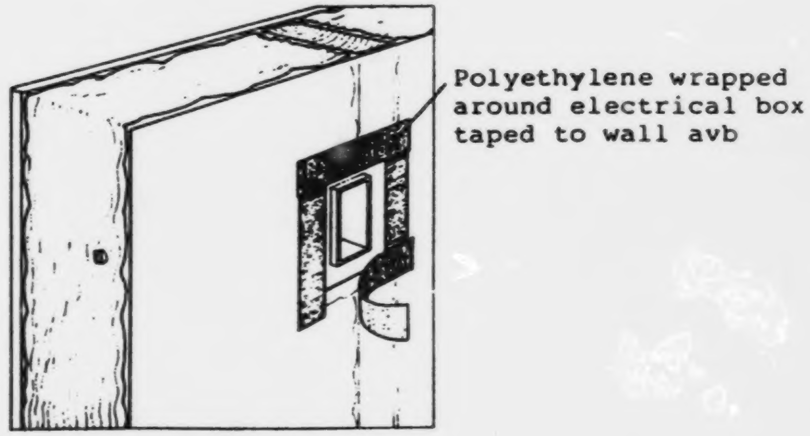

One foot wide liner strip of 6 mil polyethylene doubled back at the corners


Liner installed and sealed to diagonally cut avb
Liner folded back and stapled to rough opening
Acoustical sealant and staples

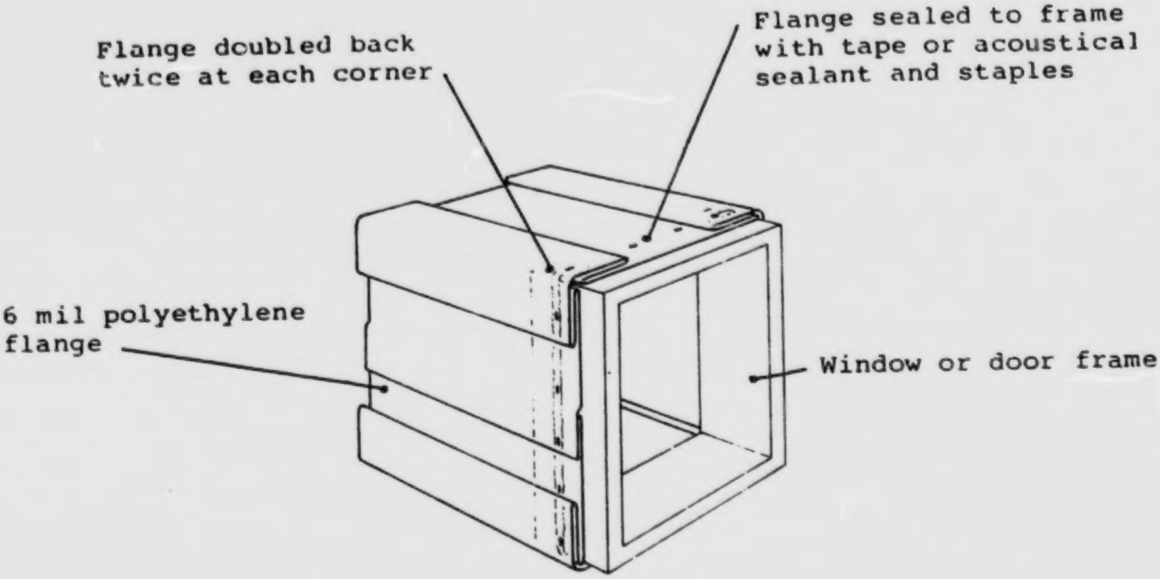
New Housing Design Details for Energy Efficiency
Air Tightness at Electrical Boxes

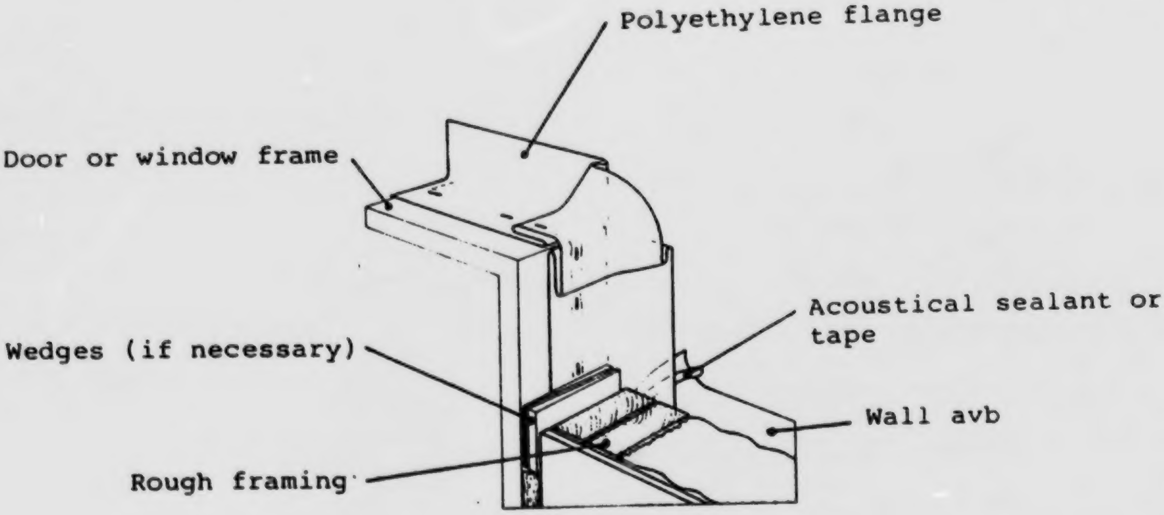

2 foot square of 6 mil polyethylene
Electrical box
Stud


Polyethylene drawn around box to form airtight bag
Wiring penetrating polyethylene sealed with tape


Polyethylene wrapped around electrical box taped to wall avb

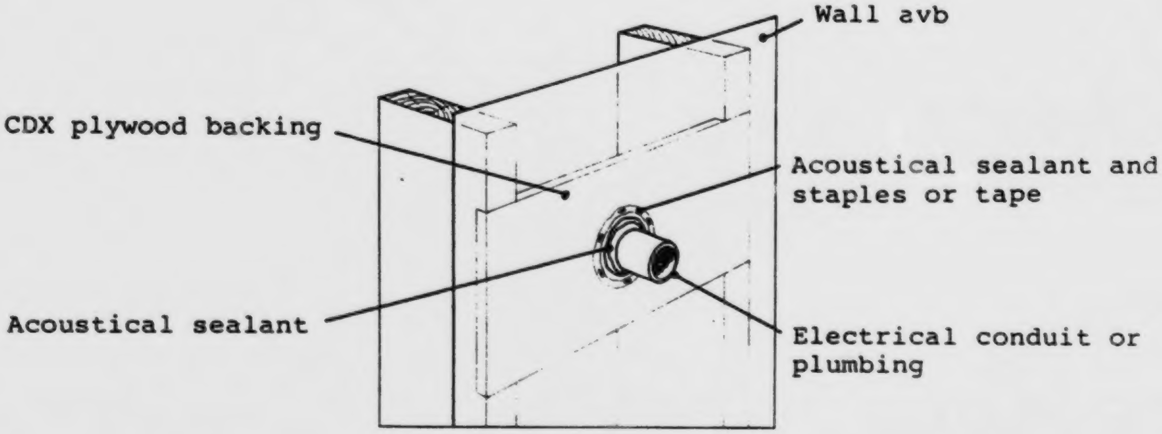
New Housing Design Details for Energy Efficiency
Air Sealing at Windows and Doors

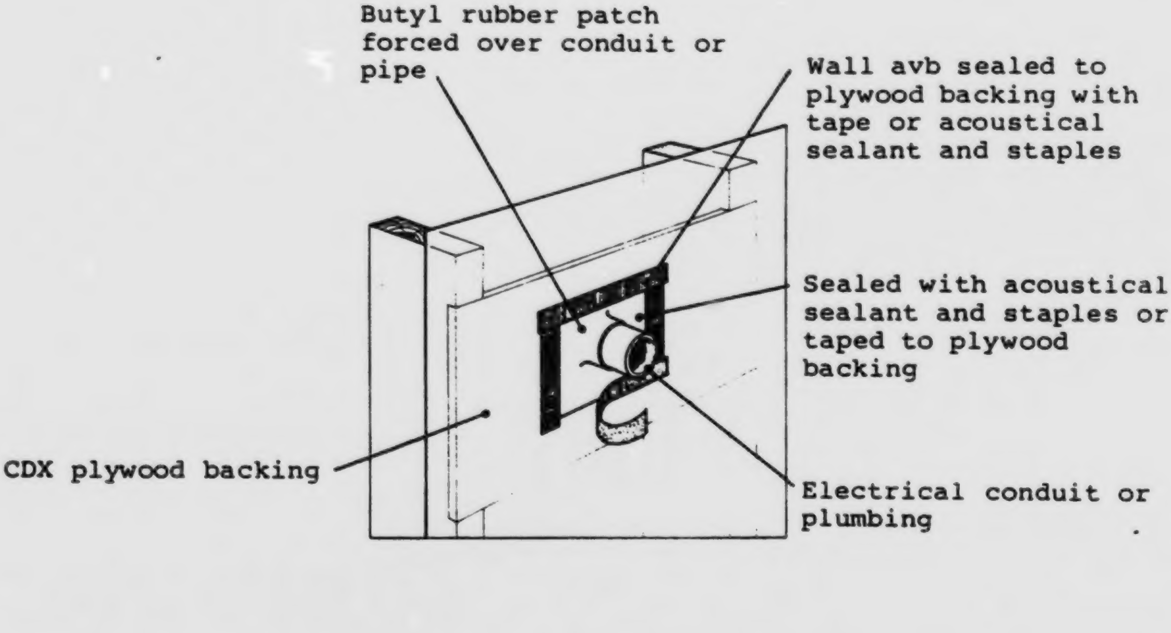

Flange doubled back twice at each corner
Flange sealed to frame with tape or acoustical sealant and staples
6 mil polyethylene flange
Window or door frame


Polyethylene flange
Door or window frame
Acoustical sealant or tape
Wedges (if necessary)
Wall avb
Rough framing

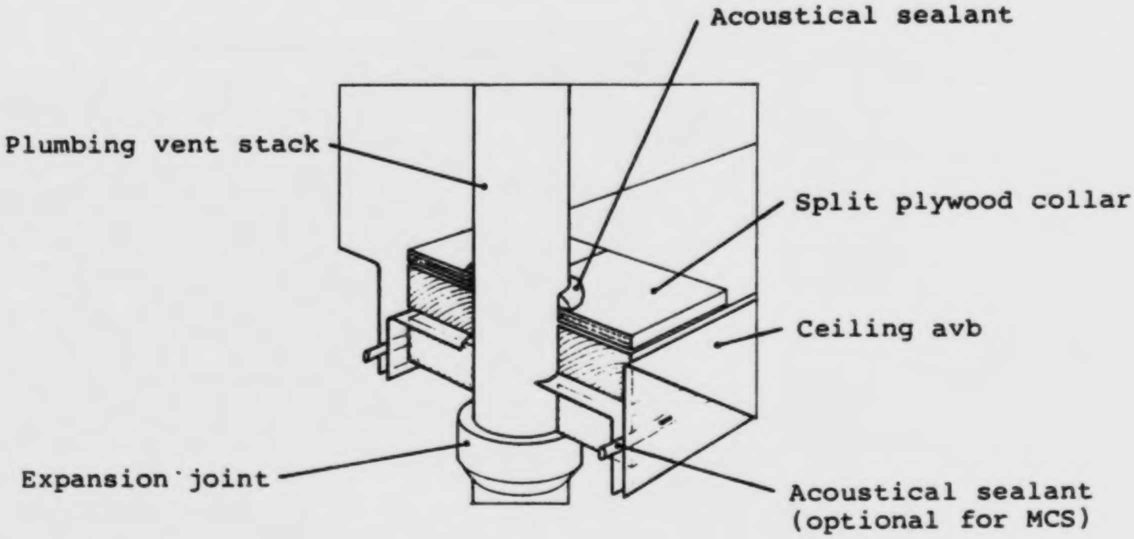
New Housing Design Details for Energy Efficiency

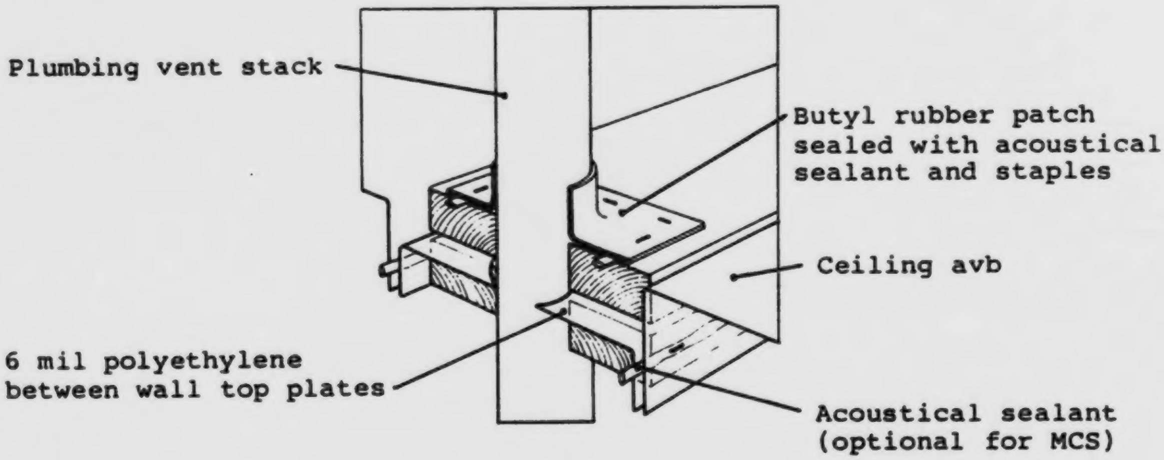
Air Sealing at Horizontal Penetrations


Wall avb
CDX plywood backing
Acoustical sealant and staples or tape
Acoustical sealant
Electrical conduit or plumbing


Butyl rubber patch forced over conduit or pipe
Wall avb sealed to plywood backing with tape or acoustical sealant and staples
Sealed with acoustical sealant and staples or taped to plywood backing
CDX plywood backing
Electrical conduit or plumbing

New Housing Design Details for Energy Efficiency
Air Sealing at Vertical Penetrations


Acoustical sealant
Plumbing vent stack
Split plywood collar
Ceiling avb
Expansion joint
Acoustical sealant (optional for MCS)


Plumbing vent stack
Butyl rubber patch sealed with acoustical sealant and staples
Ceiling avb
6 mil polyethylene between wall top plates
Acoustical sealant (optional for MCS)

APPENDIX 3 - GENERATOR RECORDS AND FUEL USE GRAPH

APPENDIX 3.1 Excerpt from Generator Log Book

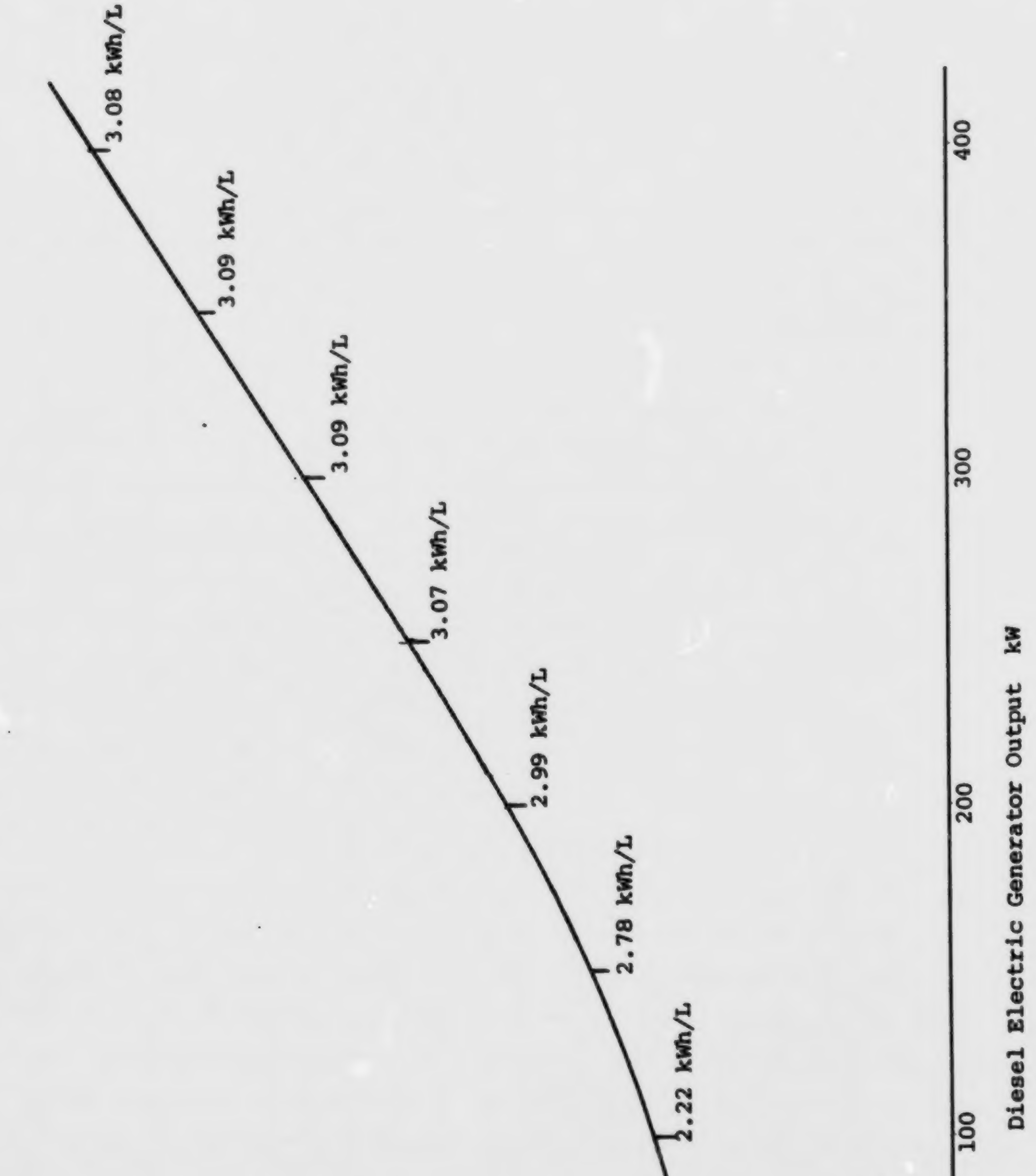
3-21.

LOG SHEET
MONTH Dec/83
KITKATLA POWER
CATERPILLAR #1
CATERPILLAR #2

	HOUR	DATE	OIL LEVEL	FREQUENCY 60	VOLTS 120	UNUSUAL NOISE	OIL LEAK	FILLED DAY TANK	KILOWATT MORNING	KILOWATT NOON	KILOWATT EVENING	TIME CHECK	ENGINEERS INIT.
SUN													
MON													
TUES													
WED													
THUR		1/83	✓	✓	✓	✓	–	✓	190	220	220	8.am	E.R.
FRI		2/83	✓	✓	✓	✓	✓	✓	180	210	220	5pm	RS
SAT		3/83	✓	✓	✓	✓	✓	✓	140 9:00am	205 1pm	220	"	RS
SUN		4/83	✓	✓	✓	✓	✓	✓	160	200	220	"	RS
MON		5/83	✓	✓	✓	✓	✓	✓	180	220	260	"	RS
TUES		6/83	✓	✓	✓	✓	✓	✓	200 9:00	210 1pm	260	[illegible]:PM	RS
WED		7/83	✓	✓	✓	✓	✓	✓	200 "	220	260	"	RS
THUR		8/83	✓	✓	✓	✓	✓	✓	200 "	220	240	5PM	RS
FRI		9/83	✓	✓	✓	✓	–	✓	200	240 1pm	280	5:PM.	RS
SAT		10/83	✓	✓	✓	✓	✓	✓	240	220 1:00	230.		RS
SUN		11/83											
MON		12/83	✓	✓	✓	✓	✓	✓	220	200	220		E.R.
TUES		13/83	✓		✓	✓	✓	✓	220	210	240		E.R.
WED		14/83							180		240		E.R.
THUR		15/83											
FRI		16/83									240		
SAT		17/83											
SUN		18/83	✓	✓	✓	✓	✓	✓	190	200	~~240~~		RS
MON		19/83	✓	✓	✓	✓	✓	✓	190	[illegible]	240	F. T.	RS
TUES		20/83	✓	✓	✓	✓	✓	✓	180	200	230		RS
WED		21/83	✓	✓	✓	✓	✓		200	200	220		RS
THUR		22/83	✓	✓	✓	✓	✓	✓	180	220	240		E.R.
FRI		23/83	✓	✓	✓	✓	✓	✓	180	220	200		E.R.
SAT		24/83							17	16	16		

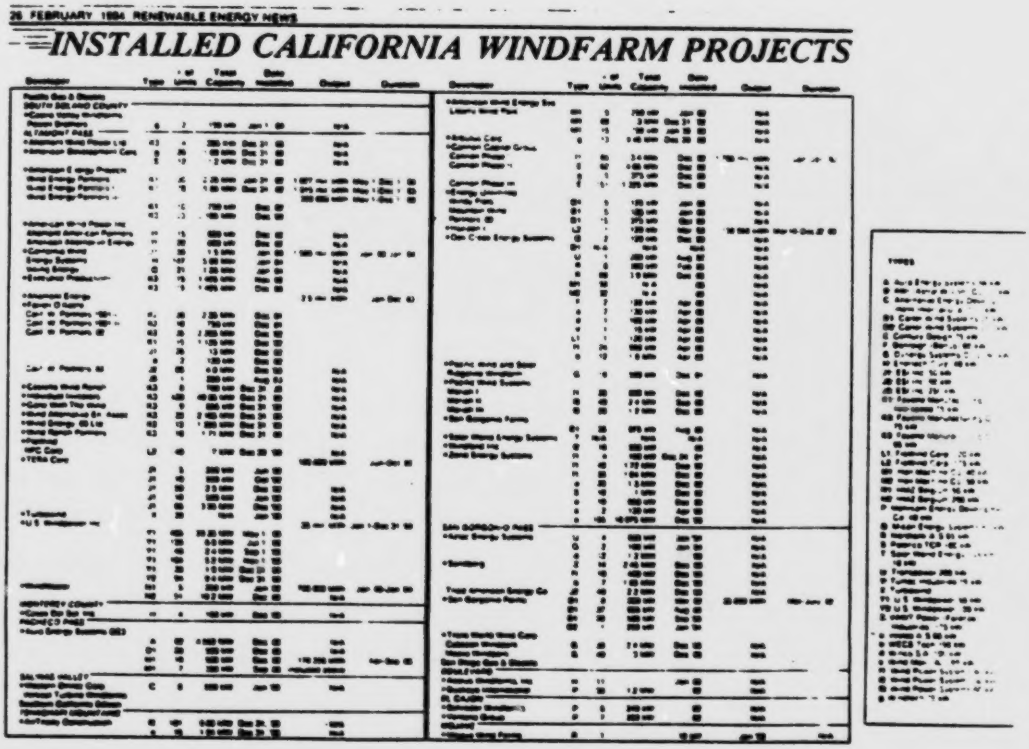
Average kW 190 214 236
Period Mean 213 kW

06672


3.08 kWh/L
3.09 kWh/L
3.09 kWh/L
3.07 kWh/L
2.99 kWh/L
2.78 kWh/L
2.22 kWh/L
0
100
200
300
400
Diesel Electric Generator Output kW
50
100
Fuel Use litres/hour

APPENDIX 4 - WIND ENERGY ASSESSMENT DETAILS

APPENDIX 4.1 Wind Turbine Installations in California



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INSTALLED CALIFORNIA WINDFARM PROJECTS

Total Machines 3867
Total Capacity 264 MW

Appendix 4.2 - Kitkatla Wind Energy Monitoring and Wind Turbine Assessment

The Kitkatla wind measuring program consisted of installing an anemometer and 20m (65 foot) tower atop the 200m hill, .7 km south of the village. The signal from the anemometer was split, one fed to the wind histogram recorder, and the other to a Campbell Scientific CR21 datalogger. These two sets of data were compared to the Atmospheric Environment Services Canada wind data records for corresponding time periods from Bonilla, Lawyer, Lucy and Triple Islands.

Data Collection - Acquisition and Records

Figure 4.1 is typical data obtained from the wind histogram recorder. It is divided into 64 "bins." The number adjacent to each bin number is the total number of two-second "counts". For example, in bin 16 there were 28909 "counts," or 28909 times two = 57818 seconds of wind measured. Each bin roughly corresponds to one mile per hour increments, or one-half metre per second. A more detailed explanation can be found in the National Research Council publication TM-WE-002, 1981, "Testing and Calibration of the DAF-Indal Ltd. Wind Histogram."

Figure 4.2 is typical data output from the Campbell Scientific CR21 datalogger and cassette tape recorder, after being played back through a signal translator onto a microcomputer printer. It is an hourly record of Julian day number, 0 to 365 for the year; time of day 1:00 to 24:00, temperature in degrees Celsius, and hourly average wind speed in metres per minute. Figure 4.2 shows day 349, December 15, hours 1 to 24, temperature +2.32 to -.03 to +2.49, hourly average winds 278.8m/min (4.6m/sec) to a high of 456m/min (7.6m/sec), and a day hour of 79.6m/min (1.3m/sec).

Figure 4.3 shows a typical daily wind record from Lucy Island which has been photo-reduced. Bonilla, Lawyer and Triple Islands had similar daily records for the period November 1983 to March 1984.

Data Processing

A copy of the wind histogram record was forwarded for analysis to T.E.S. Ltd. in Ottawa, who are under contract to analyze data for the National Research Council's wind program. A copy of their analysis and results is shown in Figures 4.4, 4.5, 4.6 and 4.7.

Analysis of the data from the wind histogram recorder was also made by SAR Engineering, to determine the mean wind speed for the time period monitored.

Hourly data from Kitkatla, and Bonilla, Lawyer, Lucy and Triple Islands (except where missing) was entered into the computer. A typical one-week data listing, December 15 to 21, is shown, photo-reduced, in Figure 4.8. Basic statistical analyses were performed on this data; mean, standard deviation, maximum, minimum and median (and others as part of the standard analysis package). Figure 4.9 is a typical output. This same data was then ordered, from lowest to highest wind speeds, as shown in Figure 4.10.

An examination of corresponding hourly data from Kitkatla and AES stations in Figure 4.8 shows trends in wind speeds between various stations. The peak winds on day 4 on the lower left of the data sheet (Figure 4.8) show Kitkatla, and Bonilla and Lucy Islands with winds in the 10m/sec range from 15:00 to 20:00 hours. Note that Lawyer Island data indicates near calm conditions. Direct hourly comparisons between stations were not made due to topographic differences and the physical separation of approximately 90 km between Bonilla Island and Triple Island, and associated weather system differences. Over a week, or longer time period, the general wind pattern differences between stations were assumed to average out and underlying fundamental station characteristics such as mean wind speed to become apparent. Thus the procedures of ordering the data, and of performing additional statistical analyses on the ordered data was appropriate.

Figures 4.10 and 4.12 show analyses on the ordered data:

- a plot of the data as a histogram or probability plot;
- a table of the data used to plot the histogram - the "actual" probability of the wind occurring at any particular speed;
- a theoretical or "predicted" probability distribution of wind speed, determined by fitting a curve to the actual data. the curve is a Weibull function for probability distribution of the form $P(>V) = e^{-(aV)^k}$. Regression analyses were performed on the data probability functions, shown in the plots of ln ln (P>V) vs ln V. These plots show a and k values for each station, from which the "predicted" distribution data in the table were derived. The analysis of variance tables at the bottom were included for reference only.

Polynomial regression analysis was performed on the ordered data, as typically shown in Figure 4.13. A first order regression on the data shows that for lower wind speeds, Kitkatla tends to have equal or greater wind speeds than Bonilla Island, while for higher wind speeds, Kitkatla experiences lower wind speeds than Bonilla Island. A perfect correlation of 1:1 would pass through the origin and have a slope of 1, i.e., pass through 10, 10, if wind speeds at both locations were equal.

The tendency at low wind speeds, for Kitkatla to have greater wind speeds than Bonilla Island is likely to cause conservative performance predictions of wind turbine electricity output.

Subfiles of the ordered and unordered data were specified for periods of time corresponding to wind histogram recording dates - approximately semi-monthly intervals. Part-week data from AES stations were combined with full week data as necessary and mean wind speeds were calculated for each corresponding time period and wind station. The results are presented as a summary in Table 11 and graphically presented in Figure 12 in the text.

The purpose of using corresponding Kitkatla wind histogram records and light station wind data was to circumvent the data problems with hourly Kitkatla records - missing data due to equipment and loss of high wind speed data due to anemometer count overflow.

These mean wind speeds for each light station were compared to Kitkatla. Bonilla Island had the closest mean value over the period of data collection: 8.43m/sec at Bonilla Island vs 8.03m/sec at Kitkatla. The output of wind turbines at Kitkatla was then calculated using long-term mean wind speed data for Bonilla Island (Figure 4.14) reduced by 5%, i.e., reduced from 8.09m/sec down to 7.69m/sec annual average, with a Weibull k value of 1.89.

Wind Turbine Performance

Two procedures were used to determine wind turbine performance - a "reference" value based upon manufacturer's data, and a value calculated using the National Research Council's "Wind Energy" computer program. This uses annual mean wind speed, Weibull coefficient k, a "figure of merit," the area swept by the rotor of the wind turbine, rated or maximum power, and the cut-out wind speed. This program was modified by SAR Engineering for iterative runs, and to operate on a Hewlett-Packard HP-85. Typical output for the DAF Indal 50 kW vertical axis turbine is shown in Figure 4.15.

The figure of merit for each wind turbine was determined by running the computer analysis for various figures of merit until the predicted annual output agreed with manufacturer's data. This figure of merit was then used for the Kitkatla station wind turbine performance using k and mean wind speeds for Kitkatla.

The wind turbine performance figures should be taken as preliminary estimates. The calculation procedure is simplistic and we believe that caution should be used on interpreting the results. As such, the figures from various machines are comparable and agree closely with manufacturer's data. Errors or differences between predicted and actual output are expected to be within accepted engineering accuracy.

Economics

The economics of the four wind turbines was assessed for six configurations: one Flowind 100 kW, one and two DAF Indal 50 kW, one ESI-54 80 kW, and one and two Enertech 45 kW machines. The cost data, output, unit cost per kWh and capital cost per kW are summarized in the accompanying Table 4.1. The lowest electrical cost occurs with the ESI-54 system, at \$ .139/kWh, based upon a 13% interest rate on borrowed money. At an interest rate of 11.5%, electricity would cost \$ .128/kWh, less than the present cost of fuel for the diesel generator.

TABLE 4.1

Economics of Wind Turbines

	FLO WIND VAWT 100 kW	DAF INDAL VAWT 50 kW 1 @ 50 kW	 2 @ 50 kW	ESI54S HAWT 50 kW	ENERTECH HAWT 45 kW 1 @ 45 kW	 2 @ 45 k
CAPITAL						
Equipment Cost $						
Machines and Tower	200,000	163,500	327,000	91,500	61,900	118,800
Electrical	40,000	40,000	45,000	40,000	40,000	45,000
Total Equipment	240,000	203,500	371,000	131,500	101,900	163,800
Delivery and Installation	40,000	37,000	52,500	38,000	37,000	60,000
Total Capitol Cost	280,000	240,500	424,500	169,500	138,900	223,800
ANNUAL						
Interest @ 13% x total capital	36,400	31,260	55,190	22,040	18,060	29,100
Depreciation @ 5% x equipment	12,000	4,070	7,440	2,630	2,040	3,280
Maintenance @ 2% x equipment	4,800	10,180	18,600	6,580	5,100	8,190
Variable @ .7mill x annual output	230	80	160	170	90	170
Total Annual Cost	53,430	45,590	81,390	31,420	25,290	40,740
ANNUAL PRODUCTION kWh	335,000	111,600	223,200	225,500	122,200	224,400
UNIT COST $/kWh	.159	.41	.36	.139	.21	.16
CAPITAL COST/kW	2,800	4,800	4,245	2,118	3,086	2,490

Figure 4.1 Wind Histogram Recorder Data Set

N.R.C. WIND SPEED DATA

End of December

Site : KITKATLA
Telephone: Data Set.

Dec 19-

LOGGED
TIME 3:46 pm
DATE JAN 2 '84 ?
BY MURRAY ASTER

SET SELECTOR SWITCH TO "COUNT" AND DISPLAY POWER SWITCH TO "ON"

BIN		COUNT					
0 0							
0 1				3	0	3	9
0 2				6	0	8	2
0 3			1	3	6	8	3
0 4			1	5	5	2	7
0 5			1	4	7	3	4
0 6			1	2	0	4	4
0 7			1	4	7	5	1
0 8			2	6	9	1	6
0 9			2	6	3	4	5
1 0			4	3	4	7	5
1 1			4	4	9	2	5
1 2			4	9	9	5	2
1 3			5	2	2	2	7
1 4			5	0	2	4	1
1 5			4	6	5	7	0
1 6			2	8	9	0	9
1 7			2	6	3	0	6
1 8			1	7	5	8	5
1 9			1	3	2	6	4
2 0				9	9	0	8
2 1				7	4	1	4
2 2				6	2	6	0
2 3				4	9	2	8
2 4				5	0	2	1
2 5				4	2	0	5
2 6				4	0	9	5
2 7				3	9	8	3
2 8				4	1	1	5
2 9				4	3	6	3
3 0				4	3	4	8
3 1				4	4	0	8

14.67

7.34 m/sec

COMMENTS :

BIN		COUNT					
3 2				4	4	5	5
3 3				4	3	3	5
3 4				4	1	3	9
3 5				3	9	7	1
3 6				3	8	5	0
3 7				3	3	6	8
3 8				3	0	1	7
3 9				2	6	6	0
4 0				2	2	7	0
4 1				1	9	6	7
4 2				1	5	6	7
4 3				1	3	2	2
4 4				1	0	5	4
4 5					8	3	1
4 6					6	9	7
4 7					5	6	2
4 8					4	2	3
4 9					3	4	6
5 0					2	4	7
5 1					1	5	8
5 2					1	2	2
5 3						9	3
5 4						5	2
5 5						3	6
5 6						2	8
5 7						2	8
5 8							4
5 9						1	0
6 0							4
6 1							2
6 2							1
6 3							

156,419

FOR NRC USE	
CHECKED	
ANALYSED	

7406893v   too much data - check tape   2 611 242

896 83/2

TURN DISPLAY POWER   RECORDING DATA

Figure 4.2   Campbell Scientific CR21 Data Set

Julian Calendar date

Temperature in °C

Time of Day, 24 hour format

Hourly Average Wind Speed in metres per minute

```
1.664 187.3
DAY: 348  TIME: 23:00
2.079 159.6
DAY: 348  TIME: 24:00
2.366 270.8
DAY: 349  TIME: 01:00
2.321 278.8
DAY: 349  TIME: 02:00
1.787 392.4
DAY: 349  TIME: 03:00
1.461 456.4
DAY: 349  TIME: 04:00
1.350 433.6
DAY: 349  TIME: 05:00
0.951 408.9
DAY: 349  TIME: 06:00
1.059 264.5
DAY: 349  TIME: 07:00
0.367 220.3
DAY: 349  TIME: 08:00
0.350 141.5
DAY: 349  TIME: 09:00
-.032 116.4
DAY: 349  TIME: 10:00  -
0.035 104.6
DAY: 349  TIME: 11:00
1.249 53.54
DAY: 349  TIME: 12:00
2.359 079.6
DAY: 349  TIME: 13:00
2.496 119.7
DAY: 349  TIME: 14:00
1.689 091.2
DAY: 349  TIME: 15:00
1.673 083.2
DAY: 349  TIME: 16:00
0.856 126.3
DAY: 349  TIME: 17:00
0.444 093.1
DAY: 349  TIME: 18:00
0.212 111.0
DAY: 349  TIME: 19:00
0.232 098.4
DAY: 349  TIME: 20:00
0.434 159.8
DAY: 349  TIME: 21:00
0.363 137.5
DAY: 349  TIME: 22:00
0.506 123.6
DAY: 349  TIME: 23:00
0.216 209.2
DAY: 349  TIME: 24:00
-.065 239.9
DAY: 350  TIME: 01:00
```

Figure 4.3 Anemograph (Wind Speed) Record from AES Lighthouse Station

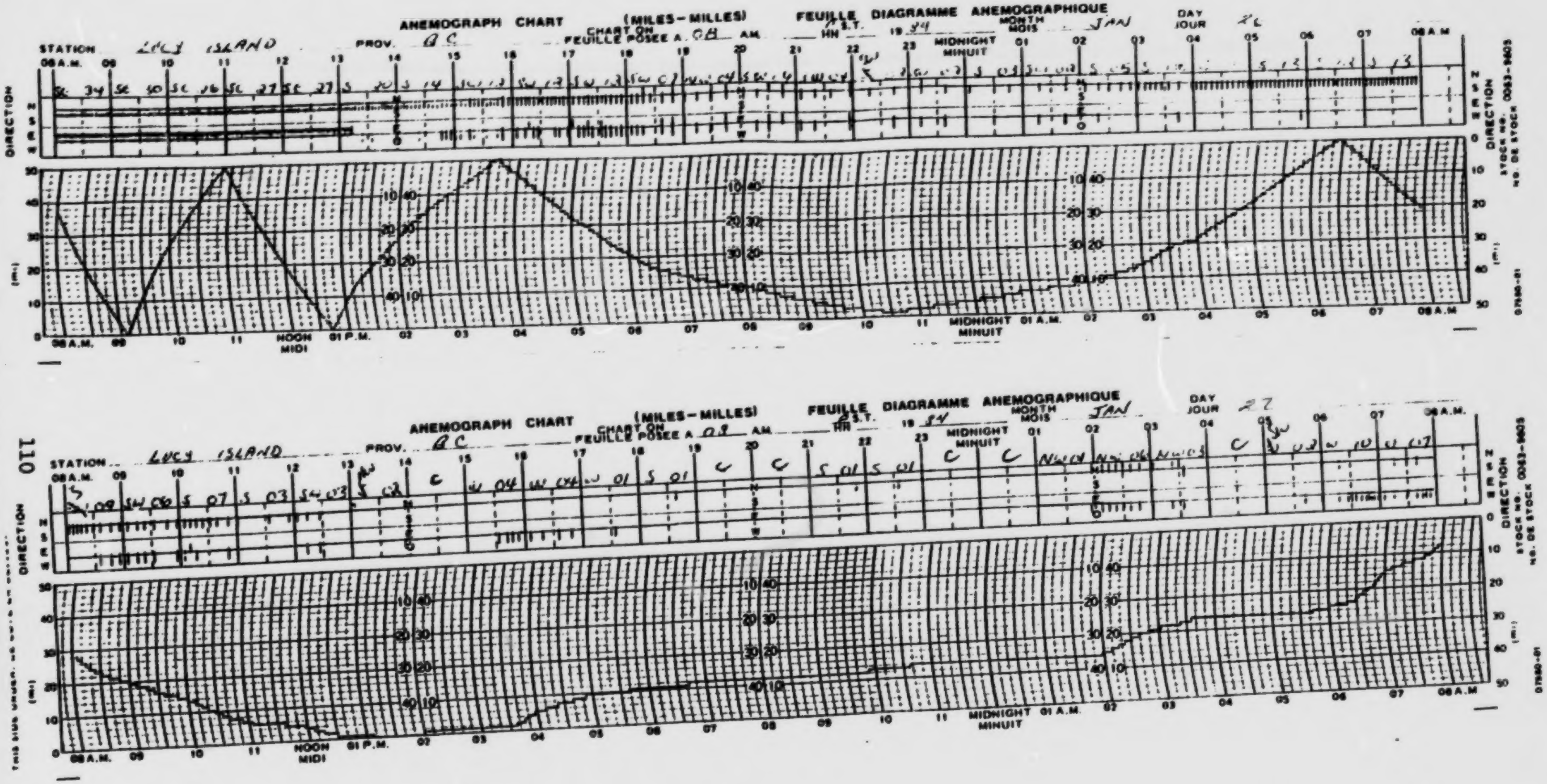


Figure 4.4 Processed Wind Histogram Data from TES Ltd.

PERFORMANCE SUMMARY FOR VAWT FIELD TRIAL KITKATLA

CUT IN WIND SPEED 6.6 m/s
OUT OUT WIND SPEED 15.6 m/s

YEAR: 1984				ESTIMATED PERFORMANCE (NO DOWN TIME)			ACTUAL PERFORMANCE						ESTIMATED OUTPUT ENERGY FROM GENERATE ONLY HISTOGRAM DATA	ACTUAL OUTPUT % OF AVAIL. WIND ENERGY	ACTUAL OUTPUT % OF EST. OUTPUT ENERGY NO DOWN TIME	ACTUAL GEN. % OF EST. GEN. TIME	DOWN TIME % OF TOTAL TIME PERIOD	ESTIMATED OUTPUT ENERGY NO DOWN TIME NO CUTOUT WIND SPEED
APPROX. MONTH OF RECORD	TOTAL TIME IN PERIOD HR	AVERAGE WIND SPEED M/S	K	AVAIL. WIND ENERGY BETZ LIMIT KW-HR.	EST. GEN. TIME HR	EST. OUTPUT ENERGY KW-HR	DOWN TIME HR	STOP TIME HR	IDLE TIME HR	ACTUAL GEN. TIME HR	ACTUAL INPUT ENERGY KW-HR	ACTUAL OUTPUT ENERGY KW-HR	KW-HR	%	%	%	%	KW-HR
JAN.	643.9	7.5	1.70	26446	278.5	5980.8												7535.5
FEB.	553.2	9.7	2.45	36615	370.6	8952.7												11011.8
MAR.																		
APR.																		
MAY																		
JUNE																		
JULY																		
AUG.																		
SEPT.																		
OCT.																		
NOV.																		
DEC.																		
SUM																		

NOTES: Explanation on following page.

Figure 4.5 Numerical Output from Wind Histogram Data Processed by TES Ltd.

MONTHLY AVERAGE WIND SPEED AND WEIBULL PARAMETER "K" AS CALCULATED FROM CONTINUOUSLY RUNNING WIND HISTOGRAM RECORDER

SITE NAME: Kitkatla

YEAR: 1984

APPROXIMATE MONTH OF RECORD	TOTAL TIME IN PERIOD HOURS	AVERAGE WIND SPEED M/S	WEIBULL PARAMETER "K"	WEIBULL PARAMETER "A"
January	643.9	7.5	1.70	0.029
February	553.2	9.7	2.45	0.003
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				
YEAR				

Notes:

Figure 4.6 Plot of Probability Function, Wind Histogram by TES Ltd.

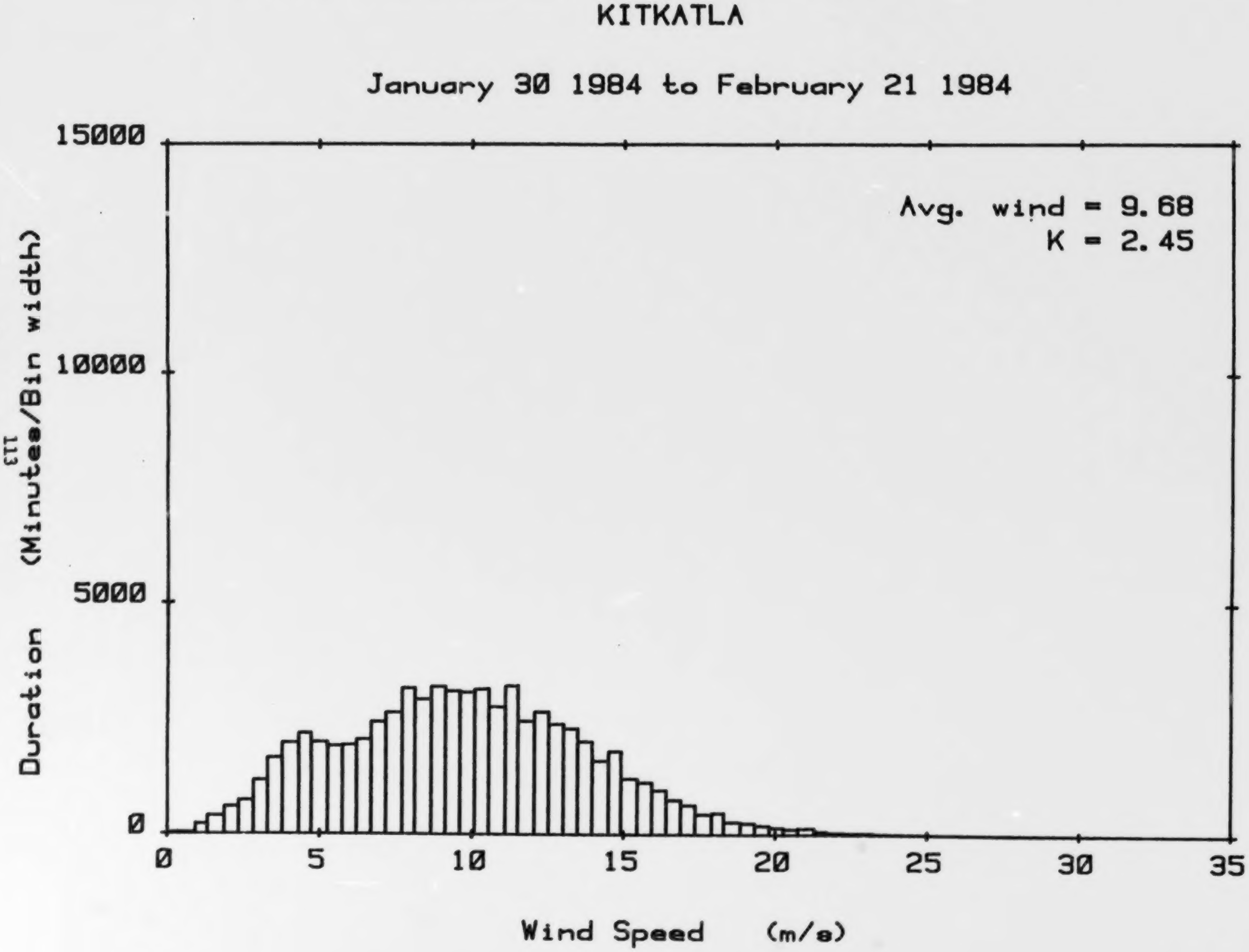
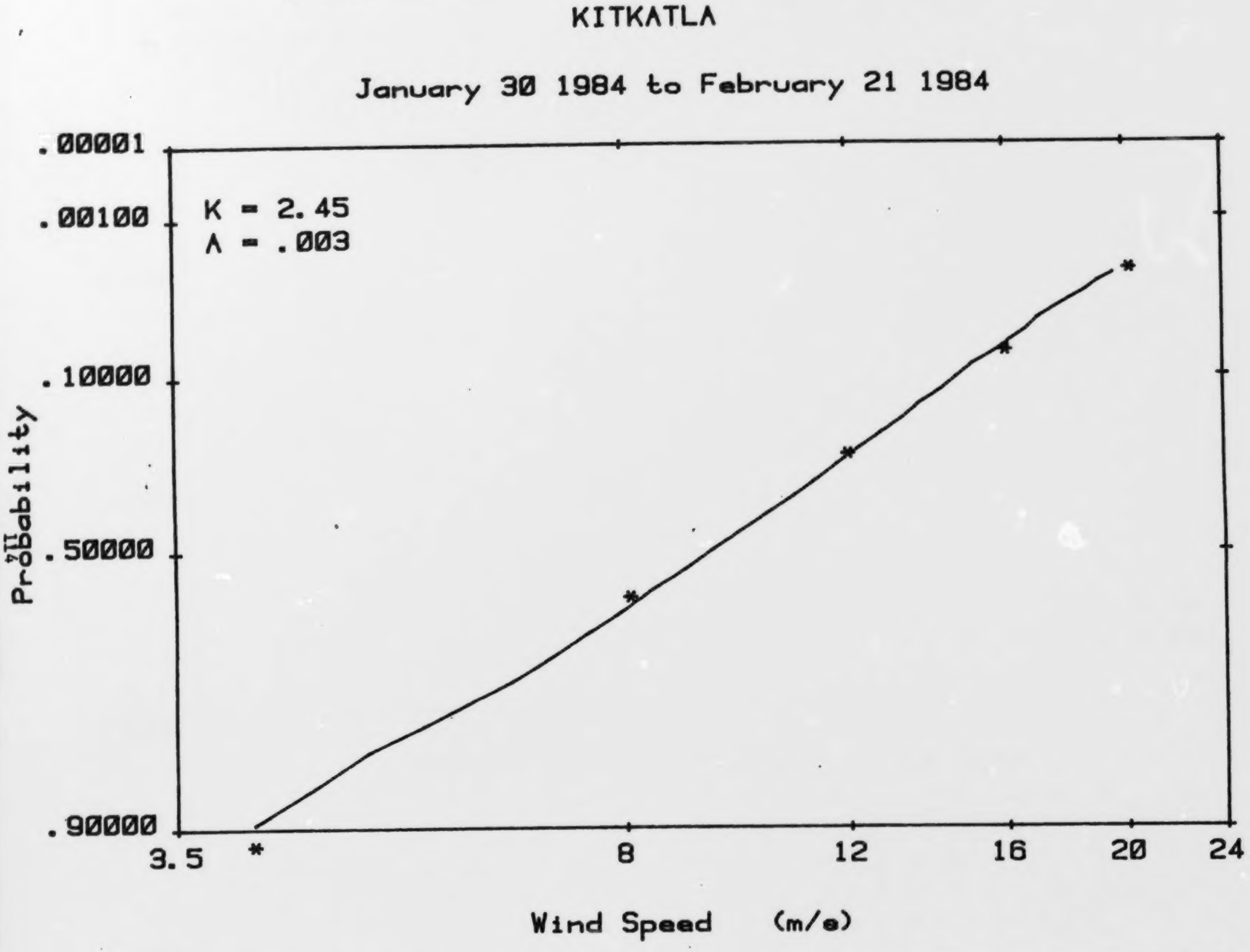


Figure 4.7 Regression Analysis of Probability Function by TES Ltd.



KITKATLA

January 30 1984 to February 21 1984

Figure 4.8 Typical Data Set Listing for Hourly Data: Kitkatla, Bonilla, Lawyer, Lucy Stations (Triple Is. missing)

```
*********************************
*        DATA LISTING           *
*        ON DATA SET            *
*.    WIND DEC 15 - DEC 21      *
*********************************

  KITKAT          LAWYEP          TRIPLE
HP        BONILA          LUCY
              m/s
01     5.1     9.6     1.9     5.3
02     7.0     8.6     1.4     7.8
03     8.1     8.6     1.4     7.9
04     7.7     7.7     1.0     6.2
05     7.3     8.2     2.9     4.9
06     4.9     7.7     2.4     3.9
07     4.1     7.2     3.4     1.4
08     2.8     7.7     0.5     1.4
09     2.4     6.7     1.4     1.4
10     2.2     4.3     3.4     4.3
11     1.4     4.3     2.4     5.2
12     1.8     4.3     2.9     6.7
13     2.5     5.3     2.9     1.9
14     2.0     4.3     3.4     1.9
15     1.9     4.8     3.4     2.4
16     2.6     4.8     2.9     4.3
17     2.0     3.4     2.4     2.4
18     2.3     3.8     2.4     2.4
19     2.1     4.3     2.4     1.9
20     3.1     4.8     3.8     1.4
21     2.8     3.4     3.4     0.5
22     2.5     2.9     2.9     1.9
23     4.0     1.4     3.9     2.9
24     4.5     2.9     4.7     2.9

01     4.8     2.4     3.8     1.0
02     4.9     2.9     4.3     2.4
03     5.2     3.8     5.3     2.4
04     5.1     4.3     4.8     2.0
05     6.1     4.3     5.8     2.4
06     6.4     5.8     6.2     2.4
07     6.0     5.8     7.7     3.8
08     5.8     5.3     7.7     2.4
09     6.9     5.8     7.2     3.4
10     6.5     1.9     7.2     1.9
11     5.8     1.4     7.7     3.4
12     6.1     3.8     8.2     2.9
13     6.3     5.8     7.2     4.3
14     5.2     3.4     7.7     4.3
15     6.2     4.8     7.7     4.3
16     5.9     4.8     8.2     3.8
17     6.8     3.8     8.2     2.4
18     6.6     5.3     7.7     2.4
19     6.8     5.8     7.7     3.4
20     6.0     5.8     7.7     3.4
21     6.5     5.3     8.2     1.9
22     4.8     5.8     7.7     1.4
23     5.0     5.8     7.7     2.8
24     5.1     5.3     8.2     2.9

01     4.0     3.8     7.7     2.4
02     4.2     3.8     7.7     2.4
03     4.7     4.8     7.7     2.4
04     4.3     3.8     7.2     2.9
05     4.0     4.8     8.2     2.9
06     3.9     4.3     8.2     1.4
07     4.4     4.3     8.2     3.4
08     5.5     3.8     7.7     1.9
09     6.0     3.8     6.2     2.9
10     5.5     2.9     7.2     2.4
11     5.0     2.4     8.2     2.4
12     5.5     2.4     7.7     2.8
13     5.5     3.8     6.2     2.4
14     6.3     3.4     6.7     0.5
15     5.4     2.4     6.2     0.5
16     5.1     2.4     6.7     4.3
17     4.8     2.4     6.2     4.3
18     5.3     2.4     6.2     3.8
19     5.8     2.4     7.2     3.8
20     6.6     2.9     7.7     3.4
21     5.5     2.4     7.2     2.4
22     5.4     2.9     7.7     0.5
23     5.6     2.9     7.7     3.8
24     5.0     2.9     7.7     1.9

01     6.4     3.4     8.6     1.4
02     5.6     3.4     7.2     2.9
03     4.8     2.9     7.2     3.4
04     5.6     2.9     6.7     1.9
05     5.7     3.4     6.7     2.9
06     4.6     4.8     3.8     4.8
07     3.9     7.7     3.4     3.8
08     4.9     7.7     3.8     4.3
09     3.6     6.7     3.4     4.8
10     4.7     6.7     2.9     5.3
11     5.5     6.2     2.9     7.2
12     5.9     6.7     2.9     7.1
13     8.1     7.6     2.4     9.1
14     9.0     8.6     1.9     9.1
15     9.1    10.1     1.0    11.0
16     8.1    11.0     1.4    12.0
17     9.3    10.1     3.4    12.9
18     7.3    10.1     2.4    13.4
19     7.4    12.5     2.4    12.9
20     6.4    12.0     3.4     5.8
21     5.8     9.6     4.8     1.4
22     5.7     9.6     2.9     3.8
23     6.7     6.2     2.9     6.7
24     7.4     5.8     4.8     4.8
```

```
01     4.8     4.8     6.2     2.4
02     5.6     4.3     5.3     1.0
03     7.3     3.8     4.3     1.4
04     6.2     4.8     4.3     1.9
05     5.7     3.4     2.4     1.9
06     6.0     1.9     3.4     2.9
07     6.2     2.9     5.8     2.9
08     6.2     3.8     6.2     0.5
09     6.3     3.8     5.8     1.4
10     6.4     4.8     5.8     2.9
11     6.2     3.4     5.3     2.9
12     6.4     2.9     4.3     2.4
13     5.9     2.4     3.4     2.4
14     5.7     1.9     5.8     2.4
15     6.8     2.4     5.8     4.8
16     6.6     1.9     3.8     4.3
17     5.5     2.4     3.4     6.3
18     5.8     2.9     4.3     6.8
19     6.8     4.8     2.9     6.7
20     7.1     5.3     3.4     5.7
21     5.6     3.8     3.4     6.2
22     5.0     3.8     2.4     5.3
23     4.9     4.8     2.4     5.8
24     4.9     5.8     2.4     6.2

01     6.0     4.3     3.4     5.7
02     6.7     4.3     2.9     5.8
03     7.5     3.8     2.9     5.3
04     7.4     4.8     5.7     5.3
05     6.4     5.3     6.7     4.3
06     7.0     3.8     4.8     3.4
07     6.8     4.7     4.3     4.2
08     7.0     4.3     4.3     6.2
09     6.8     3.8     3.8     6.2
10     7.2     4.8     3.8     6.7
11     7.8     4.8     4.7     6.7
12     7.5     4.8     5.3     6.2
13     6.3     4.8     5.8     5.3
14     7.0     4.8     5.8     4.8
15     6.6     5.3     6.2     5.3
16     6.5     6.2     5.3     6.2
17     7.6     5.8     6.2     7.2
18     7.7     5.3     5.7     6.2
19     7.0     5.2     5.8     7.7
20     7.0     6.7     7.7     6.7
21     7.8     5.8     4.3     6.7
22     7.0     5.8     3.4     7.2
23     7.0     6.2     4.8     7.2
24     7.3     6.2     4.3     6.7

01     5.8     5.3     4.8     5.3
02     5.1     4.8     3.8     4.3
03     6.1     4.8     3.8     3.8
04     5.6     5.3     4.8     4.8
05     4.4     6.2     6.7     5.6
06     5.1     6.2     4.8     6.2
07     4.7     5.8     5.8     4.8
08     5.0     5.8     7.7     5.3
09     6.9     4.8     7.2     5.8
10     6.2     4.8     7.2     5.9
11     6.7     4.3     7.7     6.7
12     7.7     4.8     8.2     7.2
13     7.7     4.3     7.7     5.8
14     8.1     4.8     7.2     5.2
15     8.2     5.3     6.7     7.2
16     7.3     5.8     6.7     7.2
17     7.8     6.7     6.2     7.6
18     8.3     6.7     6.2     8.1
19     7.3     6.2     5.3     9.6
20     7.4     6.2     8.2     8.6
21     7.3     6.2     6.6     8.7
22     7.5     7.2     8.6     7.6
23     8.6     6.2     8.2     8.7
24     8.3     5.8     8.6     7.7
```

Figure 4.9 Statistical Analysis for Typical Data Set in Figure 4.8

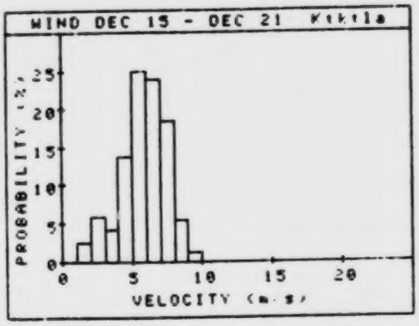
```
*********************************
*      SUMMARY STATISTICS       *
*         ON DATA SET           *
*     WIND DEC 15 - DEC 21      *
*********************************

        BASIC STATISTICS
        ----------------
Var              # of          # of
Names            Obs          Missing
Ktktla           168             0
Bonila           168             0
Lawyer           168             0
Lucy             168             0

Var
Names              Mean        Std  Dev
Ktktla            5.8275          1.5950
Bonila            4.9951          2.0489
Lawyer            5.2206          2.1046
Lucy              4.4585          2.5577

Var                              Coef of
Names          Std Error       Variation
Ktktla            .1231          27.3704
Bonila            .1581          41.0185
Lawyer            .1624          40.3137
Lucy              .1973          57.3678

Var             Coef of          Coef of
Names          Skewness         Kurtosis
Ktktla          -.6173             .3192
Bonila          1.0110            1.4000
Lawyer          -.1616           -1.1816
Lucy             .9360            1.1341

  95% CONFIDENCE INTERVAL ON MEAN
  -------------------------------

Var
Names    Lower Limit    Upper Limit
Ktktla        5.5845         6.0705
Bonila        4.6829         5.3073
Lawyer        4.8999         5.5412
Lucy          4.0688         4.8482

        CORRELATION MATRIX
        ------------------

         Bonila   Lawyer   Lucy

Ktktla   -.0081    .3338   .4603
Bonila            -.3573   .5676
Lawyer                    -.2224

         ORDER STATISTICS
         ----------------

Var
Names           Maximum        Minimum
Ktktla           9.3217         1.3623
Bonila          12.4678         1.4386
Lawyer           8.6315          .4795
Lucy            13.4268          .4795

Var
Names             Range       Midrange
Ktktla           7.9593         5.3420
Bonila          11.0292         6.9532
Lawyer           8.1520         4.5555
Lucy            12.9473         6.9532

Var
Names           Median
Ktktla          5.9800
Bonila          4.7953
Lawyer          5.2748
Lucy            3.8362

Var
Names          25-th %         75-th %
Ktktla          4.9675          6.9975
Bonila          3.8362          5.7543
Lawyer          3.3567          7.1929
Lucy            2.3976          6.2339
```

```
      CUMULATIVE PROBABILITIES
           FOR DATA SET
       WIND DEC 15 - DEC 21

   Ktktla        Lawyer        Triple
V        Bonila          Lucy
m/s  cum   probability   P(>V)

00 1.000 1.000 1.000 1.000 0.000
01 1.000 1.000 0.982 0.952 0.000
02 0.976 0.964 0.946 0.821 0.000
03 0.917 0.815 0.798 0.631 0.000
04 0.875 0.655 0.643 0.494 0.000
05 0.738 0.411 0.530 0.381 0.000
06 0.488 0.238 0.423 0.274 0.000
07 0.250 0.137 0.286 0.149 0.000
08 0.065 0.077 0.089 0.077 0.000
09 0.012 0.054 0.000 0.048 0.000
10 0.000 0.036 0.000 0.030 0.000
11 0.000 0.018 0.000 0.030 0.000
12 0.000 0.006 0.000 0.018 0.000
13 0.000 0.000 0.000 0.006 0.000
14 0.000 0.000 0.000 0.000 0.000
15 0.000 0.000 0.000 0.000 0.000
```

Figure 4.10 Ordered Data Set Listing, using data of Figure 4.8

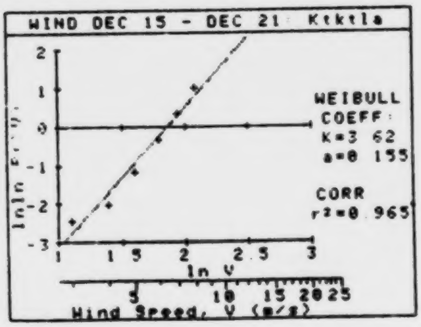
```
*********************************
*          DATA LISTING         *
*          ON DATA SET          *
*     WIND DEC 15 - DEC 21      *
*********************************

  Ktktla         Lawyer         Triple
HR       Bonila          Lucy
                m/s
01    1.4    1.4    0.5    0.5
02    1.8    1.4    1.0    0.5
03    1.9    1.9    1.0    0.5
04    2.0    1.9    1.4    0.5
05    2.0    1.9    1.4    0.5
06    2.1    1.9    1.4    1.0
07    2.2    2.4    1.4    1.0
08    2.3    2.4    1.9    1.0
09    2.4    2.4    1.9    1.4
10    2.5    2.4    2.4    1.4
11    2.5    2.4    2.4    1.4
12    2.6    2.4    2.4    1.4
13    2.8    2.4    2.4    1.4
14    2.8    2.4    2.4    1.4
15    3.1    2.4    2.4    1.4
16    3.6    2.4    2.4    1.4
17    3.9    2.4    2.4    1.4
18    3.9    2.4    2.4    1.4
19    4.0    2.9    2.4    1.4
20    4.0    2.9    2.4    1.9
21    4.0    2.9    2.4    1.9
22    4.1    2.9    2.9    1.9
23    4.2    2.9    2.9    1.9
24    4.3    2.9    2.9    1.9

01    4.4    2.9    2.9    1.9
02    4.4    2.9    2.9    1.9
03    4.5    2.9    2.9    1.9
04    4.6    2.9    2.9    1.9
05    4.7    2.9    2.9    1.9
06    4.7    2.9    2.9    1.9
07    4.7    2.9    2.9    2.4
08    4.8    3.4    2.9    2.4
09    4.8    3.4    2.9    2.4
10    4.8    3.4    2.9    2.4
11    4.8    3.4    3.4    2.4
12    4.8    3.4    3.4    2.4
13    4.9    3.4    3.4    2.4
14    4.9    3.4    3.4    2.4
15    4.9    3.4    3.4    2.4
16    4.9    3.4    3.4    2.4
17    4.9    3.8    3.4    2.4
18    5.0    3.8    3.4    2.4
19    5.0    3.8    3.4    2.4
20    5.0    3.8    3.4    2.4
21    5.0    3.8    3.4    2.4
22    5.0    3.8    3.4    2.4
23    5.1    3.8    3.4    2.4
24    5.1    3.8    3.4    2.4

01    5.1    3.8    3.4    2.4
02    5.1    3.8    3.4    2.9
03    5.1    3.8    3.8    2.9
04    5.1    3.8    3.8    2.9
05    5.2    3.8    3.8    2.9
06    5.2    3.8    3.8    2.9
07    5.3    3.8    3.8    2.9
08    5.4    3.8    3.8    2.9
09    5.4    3.8    3.8    2.9
10    5.5    3.8    3.8    2.9
11    5.5    4.3    3.8    2.9
12    5.5    4.3    3.8    2.9
13    5.5    4.3    4.3    2.9
14    5.5    4.3    4.3    2.9
15    5.5    4.3    4.3    3.4
16    5.6    4.3    4.3    3.4
17    5.6    4.3    4.3    3.4
18    5.6    4.3    4.3    3.4
19    5.6    4.3    4.3    3.4
20    5.6    4.3    4.3    3.4
21    5.6    4.3    4.3    3.4
22    5.7    4.3    4.8    3.4
23    5.7    4.3    4.8    3.4
24    5.7    4.3    4.8    3.8

01    5.7    4.3    4.8    3.8
02    5.7    4.3    4.8    3.8
03    5.8    4.8    4.8    3.8
04    5.8    4.8    4.8    3.8
05    5.8    4.8    4.8    3.8
06    5.8    4.8    4.8    3.8
07    5.8    4.8    4.8    3.8
08    5.8    4.8    5.3    3.8
09    5.9    4.8    5.3    3.8
10    5.9    4.8    5.3    3.8
11    5.9    4.8    5.3    3.8
12    6.0    4.8    5.3    3.8
13    6.0    4.8    5.3    3.8
14    6.0    4.8    5.3    4.3
15    6.0    4.8    5.3    4.3
16    6.0    4.8    5.8    4.3
17    6.1    4.8    5.8    4.3
18    6.1    4.8    5.8    4.3
19    6.1    4.8    5.8    4.3
20    6.2    4.8    5.8    4.3
21    6.2    4.8    5.8    4.3
22    6.2    4.8    5.8    4.3
23    6.2    4.8    5.8    4.3
24    6.2    4.8    5.8    4.3

01    6.2    4.8    5.8    4.8
02    6.3    4.8    6.2    4.8
03    6.3    4.8    6.2    4.8
04    6.3    5.3    6.2    4.8
05    6.3    5.3    6.2    4.8
06    6.4    5.3    6.2    4.9
07    6.4    5.3    6.2    4.8
08    6.4    5.3    6.2    4.8
09    6.4    5.3    6.2    5.3
10    6.4    5.3    6.2    5.3
11    6.4    5.3    6.7    5.3
12    6.5    5.3    6.7    5.3
13    6.5    5.3    6.7    5.3
14    6.5    5.3    6.7    5.3
15    6.6    5.3    6.7    5.3
16    6.6    5.8    6.7    5.3
17    6.6    5.8    6.7    5.3
18    6.6    5.8    6.7    5.3
19    6.7    5.8    6.7    5.3
20    6.7    5.8    6.7    5.8
21    6.7    5.8    6.7    5.8
22    6.8    5.8    6.7    5.8
23    6.8    5.8    6.7    5.8
24    6.8    5.8    6.7    5.8

01    6.8    5.8    7.2    5.8
02    6.8    5.8    7.2    5.8
03    6.8    5.8    7.2    6.2
04    6.9    5.8    7.2    6.2
05    6.9    5.8    7.2    6.2
06    7.0    5.8    7.2    6.2
07    7.0    5.8    7.2    6.2
08    7.0    5.8    7.2    6.2
09    7.0    6.2    7.2    6.2
10    7.0    6.2    7.2    6.2
11    7.0    6.2    7.2    6.2
12    7.0    6.2    7.2    6.2
13    7.0    6.2    7.2    6.2
14    7.1    6.2    7.2    6.2
15    7.2    6.2    7.2    6.7
16    7.2    6.2    7.7    6.7
17    7.3    6.2    7.7    6.7
18    7.3    6.7    7.7    6.7
19    7.3    6.7    7.7    6.7
20    7.3    6.7    7.7    6.7
21    7.3    6.7    7.7    6.7
22    7.3    6.7    7.7    6.7
23    7.4    6.7    7.7    6.7
24    7.4    6.7    7.7    7.2

01    7.4    6.7    7.7    7.2
02    7.4    7.2    7.7    7.2
03    7.5    7.2    7.7    7.2
04    7.5    7.2    7.7    7.2
05    7.5    7.2    7.7    7.2
06    7.6    7.7    7.7    7.7
07    7.7    7.7    7.7    7.7
08    7.7    7.7    7.7    7.7
09    7.7    7.7    7.7    7.7
10    7.7    7.7    8.2    7.7
11    7.8    7.7    8.2    7.7
12    7.8    8.2    8.2    8.2
13    7.8    8.6    8.2    8.2
14    8.1    8.6    8.2    8.2
15    8.1    8.6    8.2    8.6
16    8.1    9.6    8.2    8.6
17    8.1    9.6    8.2    9.1
18    8.2    9.6    8.2    9.1
19    8.3   10.1    8.2    9.1
20    8.3   10.1    8.2   11.0
21    8.6   10.1    8.6   12.0
22    9.0   11.0    8.6   12.9
23    9.1   12.0    8.6   12.9
24    9.3   12.5    8.6   13.4
```

Figure 4.11 Histogram Plot, Probability Actual vs. Predicted, Regression Analysis for Weibull Function k and a, Kitkatla and Bonilla

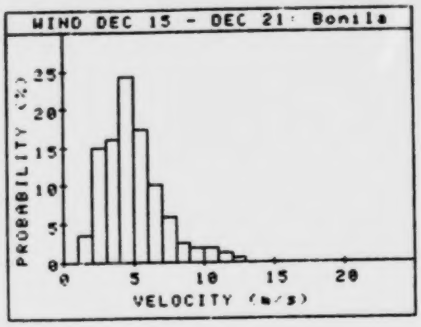


PROBABILITIES FOR Ktktla

V m/s	Actual	Pred	Diff
0	0.000	0.001	0.001
1	0.024	0.013	-0.011
2	0.060	0.046	-0.013
3	0.042	0.101	0.060
4	0.137	0.165	0.028
5	0.250	0.208	-0.042
6	0.238	0.203	-0.036
7	0.185	0.148	-0.036
8	0.054	0.078	0.025
9	0.012	0.029	0.017
10	0.000	0.007	0.007
11	0.000	0.001	0.001
12	0.000	0.000	0.000

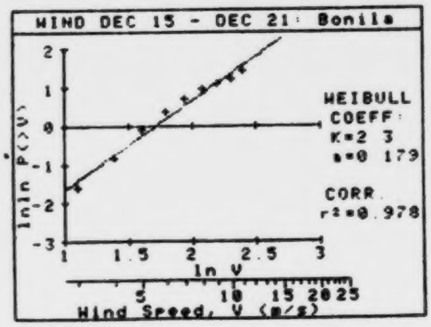


```
           AOV TABLE
SOURCE  DF  MEAN SQUARE  F-VALUE
TOTAL    5
PEGR     1      8 73868   110.15
 X^1     1      8.73868   110.15
RESID.   4       .07934
Var.  Std.Error of Coef.  T-Value
CONS            .58110    -11 62
 X^1            .34482     10.50
       95 % CONFIDENCE INTERVAL
Var     Lower Limit   Upper Limit
CONS      -6.99342      -6.51266
 X^1       3 47627       3.76154
```



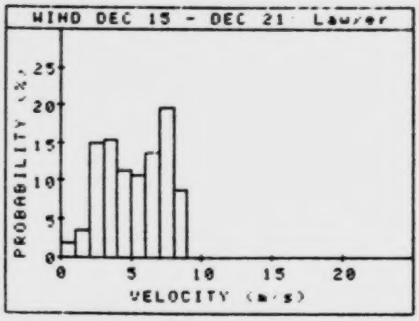
PROBABILITIES FOR Bonila

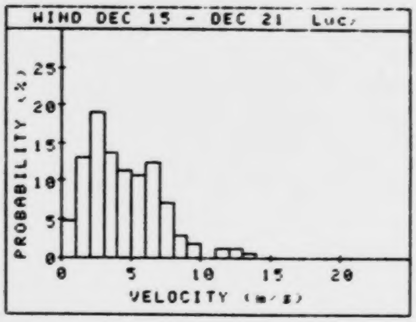
V m/s	Actual	Pred	Diff
0	0.000	0.019	0.019
1	0.036	0.071	0.036
2	0.149	0.123	-0.025
3	0.161	0.159	-0.002
4	0.244	0.168	-0.076
5	0.173	0.153	-0.020
6	0.101	0.121	0.020
7	0.060	0.084	0.025
8	0.024	0.051	0.028
9	0.018	0.028	0.010
10	0.018	0.013	-0.005
11	0.012	0.006	-0.006
12	0.006	0.002	-0.004
13	0.000	0.001	0.001
14	0.000	0.000	0.000



```
           AOV TABLE
SOURCE  DF  MEAN SQUARE  F-VALUE
TOTAL    8
REGR.    1      8.06412   314.90
 X^1     1      8.06412   314.90
RESID    7       .02561
Var.  Std.Error of Coef.  T-Value
CONS            .24700    -15.94
 X^1            .12957     17.75
       95 % CONFIDENCE INTERVAL
Var.    Lower Limit   Upper Limit
CONS      -4.04900      -3.85111
 X^1       2.24722       2.35115
```

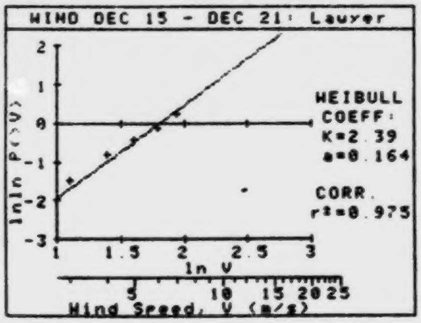
Figure 4.12 Histogram Plot, Probability Actual vs. Predicted, and REgression Analysis for Weibull Function k and a, Lawyer and Lucy

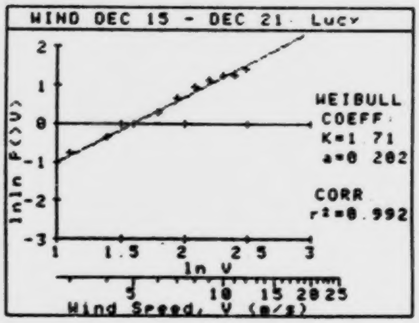




```
     PROBABILITIES FOR Lawyer

 V     Actual     Pred      Diff
m/s
 0
       0.018     0.013    -0.005
 1
       0.036     0.054     0.018
 2
       0.149     0.100    -0.049
 3
       0.155     0.138    -0.017
 4
       0.113     0.157     0.044
 5
       0.107     0.155     0.048
 6
       0.137     0.134    -0.003
 7
       0.196     0.102    -0.095
 8
       0.089     0.069    -0.021
 9
       0.000     0.041     0.041
10
       0.000     0.022     0.022
11
       0.000     0.010     0.010
12
       0.000     0.004     0.004
13
       0.000     0.002     0.002
14
       0.000     0.000     0.000
 .
```

```
     PROBABILITIES FOR Lucy

 V     Actual     Pred      Diff
m/s
 0
       0.048     0.063     0.016
 1
       0.131     0.129    -0.002
 2
       0.190     0.155    -0.036
 3
       0.137     0.154     0.018
 4
       0.113     0.137     0.024
 5
       0.107     0.112     0.005
 6
       0.125     0.085    -0.040
 7
       0.071     0.061    -0.011
 8
       0.030     0.041     0.011
 9
       0.018     0.026     0.008
10
       0.000     0.016     0.016
11
       0.012     0.009    -0.003
12
       0.012     0.005    -0.007
13
       0.006     0.003    -0.003
14
       0.000     0.001     0.001
15
       0.000     0.001     0.001
16
       0.000     0.000     0.000
```



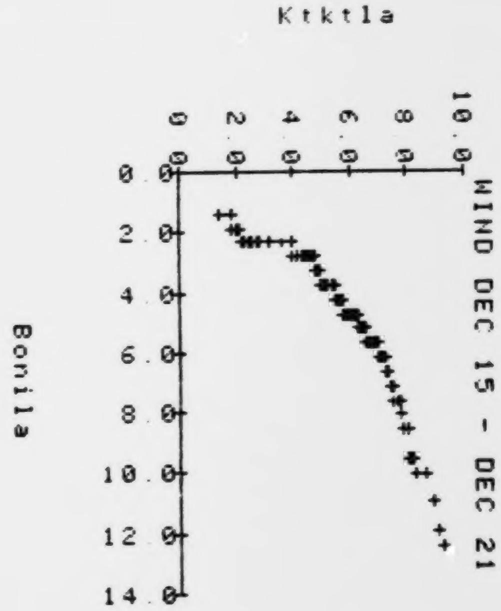


```
             AOV TABLE
SOURCE   DF  MEAN SQUARE   F-VALUE
TOTAL     5
REGR.     1      6.21387    156.68
 X^1      1      6.21387    156.68
RESID.    4       .03966
Var.  Std.Error of Coef.   T-Value
CONS              .28374    -15.27
 X^1              .19132     12.52
        95 % CONFIDENCE INTERVAL
Var.    Lower Limit    Upper Limit
CONS      -4.45024       -4.21549
 X^1       2.31573        2.47402
```

```
             AOV TABLE
SOURCE   DF  MEAN SQUARE   F-VALUE
TOTAL    10
REGR      1      9.40659   1140.03
 X^1      1      9.40659   1140.03
RESID.    9       .00832
Var.  Std.Error of Coef.   T-Value
CONS              .09506    -28.40
 X^1              .05054     33.76
        95 % CONFIDENCE INTERVAL
Var.    Lower Limit    Upper Limit
CONS      -2.76819       -2.69200
 X^1       1.68638        1.72655
```

Figure 4.13 Correlation and Regression Analysis on Ordered Data Sets for Kitkatla and Bonilla Stations

```
********************************
*    POLYNOMIAL REGRESSION     *
*         ON DATA SET          *
*    WIND DEC 15 - DEC 21      *
********************************

Dependent var   = Ktktla
Independent var. = Bonila
```



```
Variable      N                  Mean
Bonila      168               4.99509
Ktktla      168               5.82753

              Standard      Coef. of
Variable     Deviation     Variation
Bonila         2.04891       41.0185
Ktktla         1.59502       27.3704

Correlation =   .922386513507

Selected deg. of regr  =  1
R-squared = .850796880315
Std. error of est. =           .61796
```

```
                    AOV TABLE
                    ---------

SOURCE   DF    MEAN SQUARE     F-VALUE
TOTAL   167
REGR.     1      361.47230      946.58
 X^1      1      361.47230      946.58
RESID.  166         .38187


           REGRESSION COEFFICIENTS
Var.  Std.Format             E-Format
CONS      2.2408     2.24079755E+000
 X^1       .7181     7.18051674E-001

Var.    Std.Error of Coef.    T-Value
CONS               .12595       17.79
 X^1               .02334       30.77


           95 % CONFIDENCE INTERVAL
Var.      Lower Limit     Upper Limit
CONS          1.99207         2.48953
 X^1           .67196          .76414
```

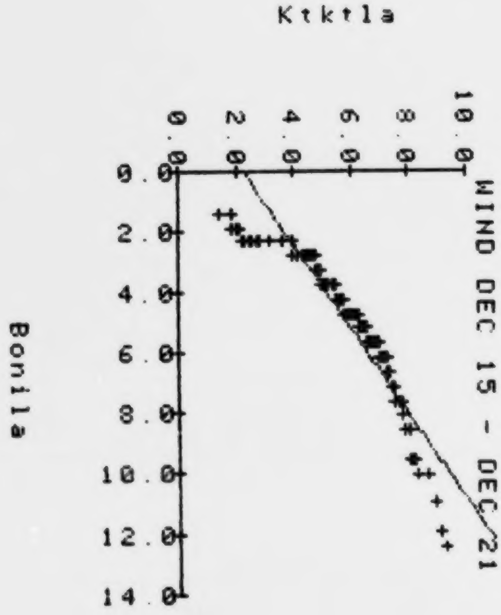


Figure 4.14 Long Term Wind Speed Data for Bonilla Island (ESL/IBI 1981)

STATION : BONILLA IS.
LOCATION: LAT 53 30 LONG 130 38

PERIOD OF RECORD: 1957-1975
HT. ABOVE GROUND: 45 FT.

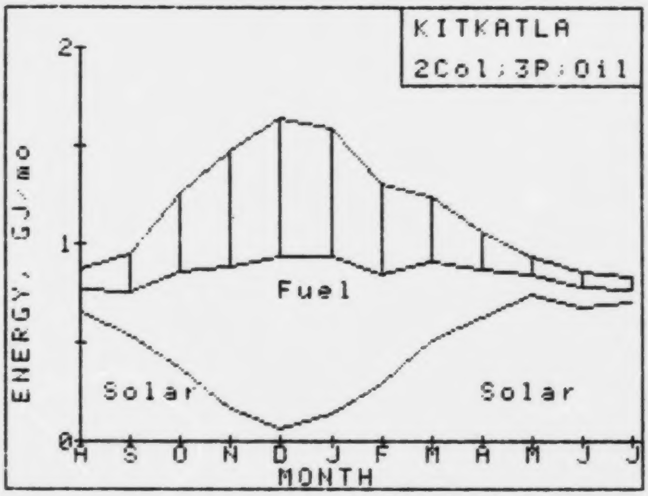
	----- NUMBER	OF	HOURS	(SPEED	WIND IN	SPEED MPH)	IS	EXCEEDED		------	MEAN SPEED MPH m/sec	K DIST'N EXP'NT
	0.	1.0	4.0	8.0	13.0	19.0	25.0	32.0	39.0	47.0	55.0		
JAN	743.5	740.2	727.4	658.5	508.1	352.5	214.8	105.4	43.8	17.1	4.0	19.4 861	1.97
FEB	677.0	674.2	658.1	602.6	489.5	369.4	234.7	123.9	58.6	19.3	3.5	21.0939	1.90
MAR	743.9	734.9	708.5	638.2	508.7	348.9	203.5	81.6	30.4	9.7	2.4	18.6832	1.88
APR	719.5	717.3	701.0	630.4	511.9	357.6	205.9	84.2	29.0	6.8	1.3	19.2858	1.99
MAY	743.8	739.0	711.7	613.2	455.9	292.1	141.0	47.3	12.5	1.5	.0	16.4133	1.89
JUN	720.0	716.3	684.0	585.2	439.7	255.1	88.8	18.9	3.6	.5	.0	15.4638	2.06
JUL	743.6	738.8	694.5	599.6	425.3	189.6	53.3	9.8	.6	.0	.0	14.0626	2.17
AUG	743.6	737.4	695.5	583.7	422.0	217.1	81.9	19.3	4.3	.3	.0	14.5648	1.95
SEP	719.5	717.0	690.6	598.5	464.5	285.4	126.4	40.3	11.7	1.1	.0	16.6742	1.99
OCT	743.2	737.0	712.8	641.1	522.1	374.8	244.2	122.7	55.1	18.4	4.6	20.1899	1.77
NOV	719.9	718.0	694.2	629.1	516.7	370.3	226.7	109.0	52.5	19.1	3.8	20.1899	1.90
DEC	744.1	743.1	729.1	668.6	558.8	413.4	272.5	144.3	64.3	21.5	4.5	21.5961	1.97
YEAR	8761.6	8713.2	8407.4	7448.7	5823.2	3826.2	2093.7	906.7	366.4	115.3	24.1	18.1809	1.89

Figure 4.15 Wind Turbine Output Analysis for 50 kW Vertical Axis Wind Turbine, based on NRC's annual output computer model.

```
INPUTS:
------
Avg wind spd(m/s)   =        7.69
Weibull Coeff., K   =        1.89
Air density (kg/m3)=         1.226
'mill fig. of merit=         1.10
Swept area (m2)     =      121.50
'mill max pwr (kW) =        50.0
Cut-out speed (m/s)=        15.65

PERFORMANCE:
-----------
Pavg/Pmax           =        0.255
Energy o/p (kWh/yr)=  111586.
Cut-in speed (m/s) =         5.9
Operation (hrs/yr) =     4996.9
Pwr loading coeff. =         1.476
******************************
```

APPENDIX 5 - SOLAR WATER HEATER SYSTEM CALCULATIONS

Figure 5.1 Solar Water Heater System Calculations

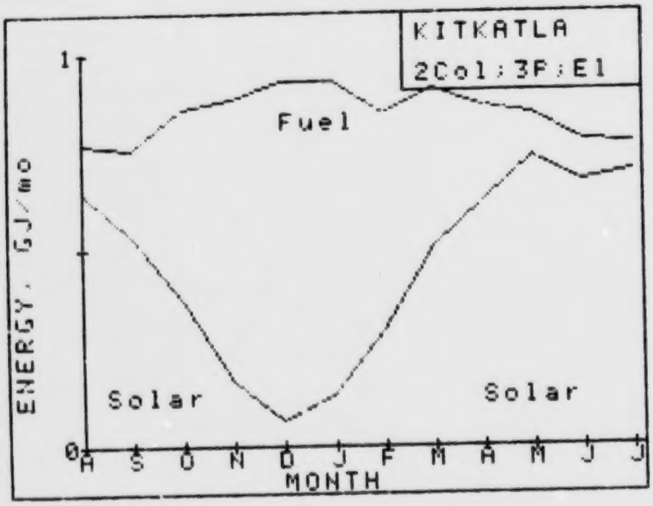


```
   SOLAR PERFORMANCE (GJ/mo)
MO.      LOAD   SOLAR DEMAND    FUEL
A        0.76    0.64   0 12    0.22
S        0.76    0.53   0.23    0 41
O        0.85    0.37   0.49    0.89
N        0.88    0.16   0.72    1.30
D        0 93    0.06   0 86    1.57
J        0.93    0.13   0 80    1.45
F        0.85    0.29   0 55    1 00
M        0 91    0.51   0.40    0.73
A        0.86    0.62   0.24    0.44
M        0.85    0.73   0 11    0 20
J        0.77    0.67   0 10    0 19
J        0.76    0.69   0 07    0 13
YR.     10.11    5.42   4.69    8.53

ANNUAL SOLAR FRACTION =      .53

ANNUAL FUEL COST =       $ 90.18
  (Fuel at $ 9.4 /GJ)
```

```
KITKATLA DHW:2Col;140L/d:Oil

 COST           $ 4200.00
 SAVINGS $/yr      92.63

 Interest          12.00
 Discount          10.00
 Inflation         12.00
 Finance           20 yrs

 YEAR   CUM. NPV ($)
  01        -427.
  02        -806.
  03       -1141.
  04       -1436.
  05       -1695.
  06       -1920.
  07       -2115.
  08       -2282.
  09       -2423.
  10       -2541.
  11       -2637.
  12       -2713.
  13       -2772.
  14       -2813.
  15       -2840.
  16       -2852.
  17       -2850.
  18       -2837.
  19       -2813.
  20       -2778.
```

```
SYSTEM PARAMETERS               VALUES
Collector: Area (m2)              4.04
  Loss Coeff. (W/Cm2)             3.2
  FR(Mean τα)                      .63
  Azimuth.Slope (deg.)          180.3
  Ht. exch. coeff.                1.00
Demand exch. coeff.                .86
Demand water temp. (C)          55
Water Supply temp. (C)          M4
Water Demand (L/day)            140
Aux. Seasonal eff.                 .55
Fuel rate ($/GJ)                  9.4

 KITKATLA DHW
 2Col; 3Pers; Oil
```

Figure 5.2 Solar Water Heater System Calculations

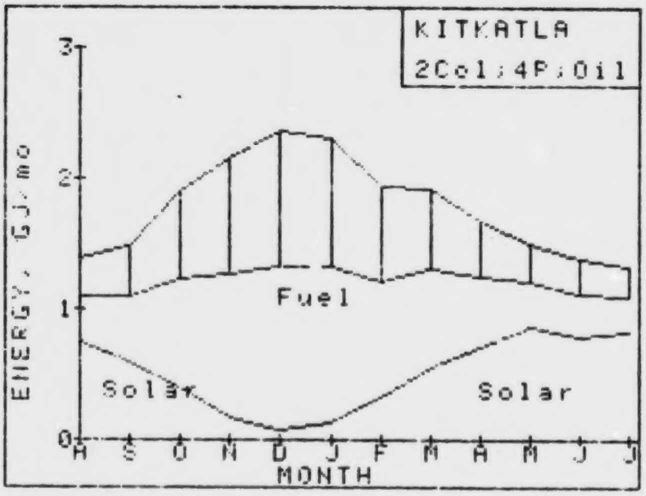


```
   SOLAR PERFORMANCE (GJ/mo)
MO.      LOAD   SOLAR  DEMAND    FUEL
A        0.76   0.64    0.12     0.12
S        0.76   0.53    0.23     0 23
O        0.85   0.37    0.49     0.49
N        0.88   0.16    0.72     0.72
D        0.93   0.06    0.86     0.86
J        0.93   0.13    0.80     0.80
F        0.85   0.29    0.55     0.55
M        0.91   0.51    0.40     0.40
A        0.86   0.62    0.24     0.24
M        0.85   0.73    0.11     0.11
J        0.77   0.67    0.10     0.10
J        0.76   0.69    0 07     0.07
YR      10.11   5.42    4.69     4.69

ANNUAL SOLAR FRACTION =        .53

ANNUAL FUEL COST =         $ 189.06
  (Fuel at $ 40.3 /GJ)
```

```
SYSTEM PARAMETERS              VALUES
Collector: Area (m2)             4.04
  Loss Coeff. (W/Cm2)            3.2
  FR(Mean τα)                     .63
  Azimuth Slope (deg.)         180.3
  Ht  exch. coeff.               1.00
Demand exch. coeff.                86
Demand water temp. (C)         55
Water Supply temp. (C)         M4
Water Demand (L/day)          140
Aux. Seasonal eff.               1.00
Fuel rate ($/GJ)                 40.3

  KITKATLA DHW
  2Col; 3Pers; Elec
```

```
KITKATLA DHW:2Col;140L/d;Elec

 COST          $ 4200.00
 SAVINGS $/yr   218.43

 Interest        12.00
 Discount        10.00
 Inflation       12.00
 Finance         20 yrs

 YEAR   CUM. NPV ($)
  01        -313.
  02        -575.
  03        -792.
  04        -966.
  05       -1102.
  06       -1202.
  07       -1269.
  08       -1306.
  09       -1315.
  10       -1299.
  11       -1258.
  12       -1195.
  13       -1111.
  14       -1009.
  15        -888.
  16        -750.
  17        -596.
  18        -428.
  19        -245.
  20         -49.
```

Figure 5.3 Solar Water Heater System Calculations

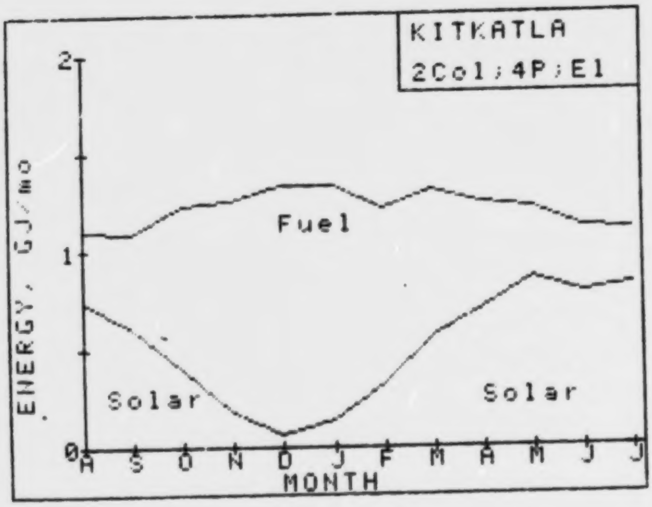


```
    SOLAR PERFORMANCE (GJ/mo)
MO.      LOAD   SOLAR DEMAND    FUEL
A        1.09   0.74   0.35     0.63
S        1.08   0.59   0.49     0.89
O        1.22   0.39   0.83     1.51
N        1.26   0.17   1.09     1.98
D        1.32   0.06   1.26     2.29
J        1.32   0.13   1.19     2.17
F        1.21   0.31   0.90     1.63
M        1.30   0.55   0.74     1.35
A        1.23   0.70   0.53     0.97
M        1.21   0.86   0.35     0.64
J        1.11   0.78   0.32     0.59
J        1.09   0.81   0.28     0.51
YR.     14.44   6.11   8.33    15.15

ANNUAL SOLAR FRACTION =      0.42

ANNUAL SOLAR SAVINGS = $ 104.45

ANNUAL FUEL COST =       $ 142.40
  (Fuel at $ 9.4 /GJ)
```

```
KITKATLA DHW: 2 col.; 200 L/d

 COST          $ 4200.00
 SAVINGS $/yr   104.43

 Interest        12.00
 Discount        10.00
 Inflation       12.00
 Finance         20 yrs

 YEAR   CUM. NPV ($)
  01        -416.
  02        -784.
  03       -1108.
  04       -1392.
  05       -1639.
  06       -1853.
  07       -2036.
  08       -2190.
  09       -2319.
  10       -2424.
  11       -2508.
  12       -2571.
  13       -2616.
  14       -2644.
  15       -2657.
  16       -2654.
  17       -2639.
  18       -2611.
  19       -2572.
  20       -2522.
```

```
SYSTEM PARAMETERS              VALUES
Coilector: Area (m2)              4.04
  Loss Coeff. (W/Cm2)             3.2
  FR(Mean τα)                      .63
  Azimuth.Slope (deg.)          180.3
  Ht. exch. coeff.                1.00
Demand exch. coeff                 .86
Demand water temp. (C)          55
Water Supply temp. (C)          M4
Water Demand (L/day)           200
Aux. Seasonal eff.                 .55
Fuel rate ($/GJ)                  9.4

 KITKATLA DHW
 2Col; 4Pers; Oil
```

Figure 5.4 Solar Water Heater System Calculations



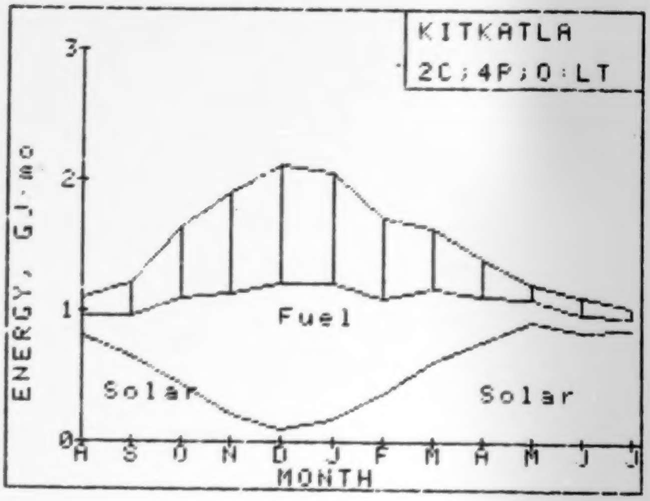
```
   SOLAR PERFORMANCE (GJ/mo)
MO.      LOAD  SOLAR DEMAND   FUEL
A        1.09   0.74   0.35   0.35
S        1.08   0.59   0.49   0.49
O        1.22   0.39   0.83   0.83
N        1.26   0.17   1.09   1.09
D        1.32   0.06   1.26   1.26
J        1.32   0.13   1.19   1.19
F        1.21   0.31   0.90   0.90
M        1.30   0.55   0.74   0.74
A        1.23   0.70   0.53   0.53
M        1.21   0.86   0.35   0.35
J        1.11   0.78   0.32   0.32
J        1.09   0.81   0.28   0.28
YR.     14.44   6.11   8.33   8.33

ANNUAL SOLAR FRACTION =      .42

ANNUAL FUEL COST =       $ 335.76
  (Fuel at $ 40.3 /GJ)
```

```
KITKATLA DHW: 2 col.; 200 L/d

 COST          $ 4200.00
 SAVINGS $/yr    246.23

 Interest        12.00
 Discount        10.00
 Inflation       12.00
 Finance         20 yrs
```

```
SYSTEM PARAMETERS              VALUES
Collector: Area (m2)             4.04
  Loss Coeff. (W/Cm2)            3.2
  FR(Mean τσ)                     .63
  Azimuth.Slope (deg.)         180.3
  Ht. exch. coeff.               1.00
Demand exch. coeff.               .86
Demand water temp. (C)          55
Water Supply temp. (C)          M4
Water Demand (L/day)           200
Aux. Seasonal eff.               1.00
Fuel rate ($/GJ)                40.3

 KITKATLA DHW
 2Col; 4Pers; Elec
```

```
YEAR  CUM. NPV ($)
 01       -287.
 02       -524.
 03       -715.
 04       -862.
 05       -971.
 06      -1043
 07      -1082.
 08      -1091.
 09      -1071.
 10      -1024.
 11       -953.
 12       -860.
 13       -745.
 14       -610.
 15       -456.
 16       -285.
 17        -98.
 18        105.
 19        323.
 20        554.
```

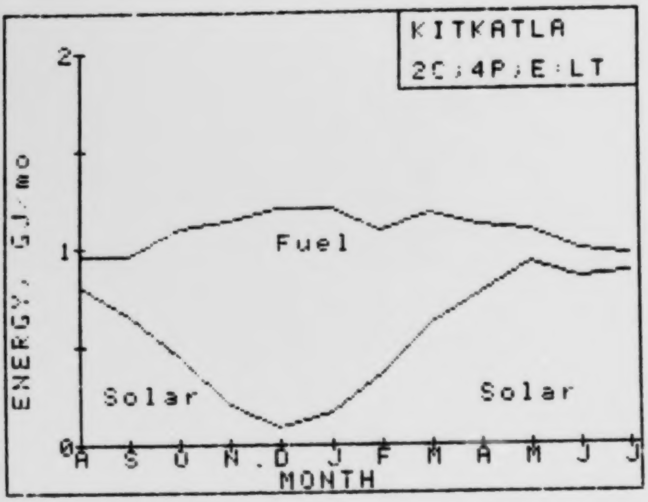
Figure 5.5 Solar Water Heater System Calculations



```
   SOLAR PERFORMANCE (GJ/mo)
MO.      LOAD   SOLAR DEMAND    FUEL
A        0.96    0.80   0.17    0.30
S        0.96    0.64   0.31    0.56
O        1.09    0.44   0.65    1.19
N        1.13    0.20   0.94    1.70
D        1.20    0.08   1.11    2.03
J.       1.20    0.16   1.04    1.89
F        1.09    0.35   0.74    1.35
M        1.17    0.61   0.56    1.02
A        1.11    0.76   0.35    0.63
M        1.08    0.92   0.16    0.29
J        0.98    0.84   0.14    0.26
J        0.96    0.87   0.10    0.17
YR.     12.91    6.65   6.26   11.39

ANNUAL SOLAR FRACTION =       .51

ANNUAL FUEL COST =       $ 107.04
  (Fuel at $ 9.4 /GJ)
```

```
SYSTEM PARAMETERS              VALUES
Collector: Area (m2)             4.04
  Loss Coeff. (W/Cm2)            3.2
  FR(Mean τα)                     .63
  Azimuth.Slope (deg.)         180.3
  Ht  exch. coeff.               1.00
Demand exch. coeff.               .95
Demand water temp. (C)          50
Water Supply temp. (C)          M4
Water Demand (L/day)           200
Aux. Seasonal eff.                .55
Fuel rate ($/GJ)                 9.4

 KITKATLA DHW
 2C;4P;Oil:Lo T;T in T
```

Figure 5.6 Solar Water Heater System Calculations



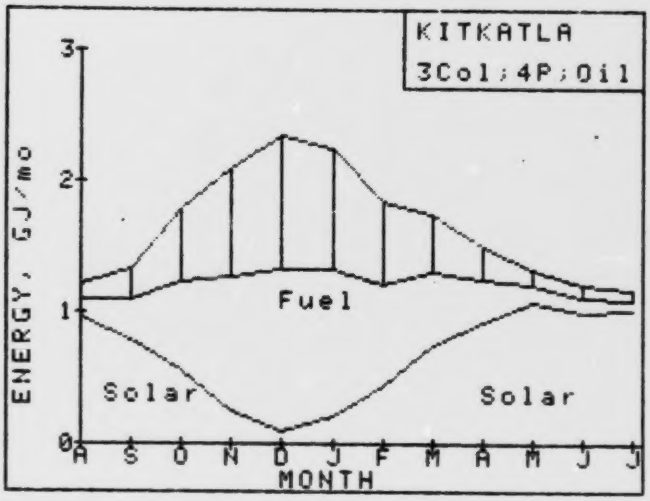
```
   SOLAR PERFORMANCE (GJ/mo)
MO.      LOAD  SOLAR DEMAND    FUEL
A        0.96   0.80   0.17    0.17
S        0.96   0.64   0.31    0.31
O        1.09   0.44   0.65    0.65
N        1.13   0.20   0.94    0.94
D        1.20   0.08   1.11    1.11
J        1.20   0.16   1.04    1.04
F        1.09   0.35   0.74    0.74
M        1.17   0.61   0.56    0.56
A        1.11   0.76   0.35    0.35
M        1.08   0.92   0.16    0.16
J        0.98   0.84   0.14    0.14
J        0.96   0.87   0.10    0.10
YR.     12.91   6.65   6.26    6.26

ANNUAL SOLAR FRACTION =        .51

ANNUAL FUEL COST =        $ 252.4
  (Fuel at $ 40.3 /GJ)
```

SYSTEM PARAMETERS	VALUES
Collector: Area (m2)	4.04
Loss Coeff. (W/Cm2)	3.2
FR(Mean τα)	.63
Azimuth.Slope (deg.)	180.3
Ht. exch. coeff.	1.00
Demand exch. coeff.	.95
Demand water temp. (C)	50
Water Supply temp. (C)	M4
Water Demand (L/day)	200
Aux. Seasonal eff.	1.00
Fuel rate ($/GJ)	40.3

KITKATLA DHW
2C;4P;E:LoT;T in T

```
KITKATLA DHW:2Col;200L/d:Elec

 COST          $ 4200.00
 SAVINGS $/yr   268.00

 Interest        12.00
 Discount        10.00
 Inflation       12.00
 Finance         20 yrs

 YEAR  CUM. NPV ($)
  01       -268.
  02       -484.
  03       -654.
  04       -781.
  05       -868.
  06       -919.
  07       -936.
  08       -922.
  09       -879.
  10       -809.
  11       -715.
  12       -597.
  13       -457.
  14       -297.
  15       -119.
  16         78.
  17        292.
  18        522.
  19        767.
  20       1027.
```

Figure 5.7 Solar Water Heater System Calculations

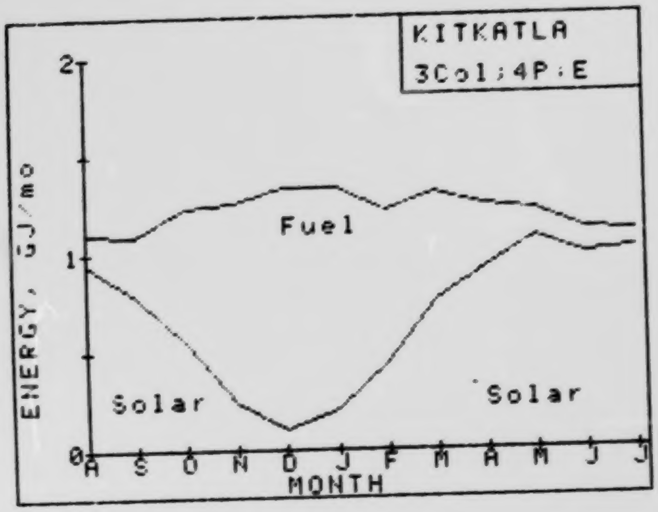


```
   SOLAR PERFORMANCE (GJ/mo)
MO.      LOAD   SOLAR DEMAND    FUEL
A        1.09   0.94   0.15    0 27
S        1.08   0.78   0 30    0 55
O        1.22   0.54   0.68    1 23
N        1.26   0.24   1 01    1.84
D        1.32   0.10   1 23    2.24
J        1.32   0.19   1 13    2 06
F        1.21   0.43   0.77    1.41
M        1.30   0.75   0 55    1.00
A        1.23   0.91   0.32    0 58
M        1.21   1.07   0.13    0.24
J        1.11   0.98   0.12    0.22
J        1.09   1.01   0 08    0 14
YR.     14.44   7.97   6.48   11.78

ANNUAL SOLAR FRACTION =       55

ANNUAL FUEL COST =       $ 110 68
  (Fuel at $ 9.4 /GJ)
```

```
KITKATLA DHW:3Col;200L/d;Oil

 COST         $ 5200.00
 SAVINGS $/yr   136.21

 Interest         12.00
 Discount         10.00
 Inflation        12.00
 Finance          20 yrs

 YEAR  CUM. NPV ($)
  01       -509.
  02       -958.
  03      -1353.
  04      -1698.
  05      -1997.
  06      -2254.
  07      -2474.
  08      -2658.
  09      -2810.
  10      -2933.
  11      -3029.
  12      -3100.
  13      -3147.
  14      -3174.
  15      -3182.
  16      -3171.
  17      -3143.
  18      -3100.
  19      -3043.
  20      -2972.
```

```
SYSTEM PARAMETERS              VALUES
Collector: Area (m2)             6.06
  Loss Coeff. (W/Cm2)            3.2
  FR(Mean τα)                     .63
  Azimuth.Slope (deg.)         180.3
  Ht. exch. coeff.               1.00
Demand exch. coeff.               .86
Demand water temp. (C)         55
Water Supply temp. (C)         M4
Water Demand (L/day)          200
Aux. Seasonal eff.                .55
Fuel rate ($/GJ)                 9.4

 KITKATLA DHW
 3Col; 4Pers; Oil
```

Figure 5.8 Solar Water Heater System Calculations



```
   SOLAR PERFORMANCE (GJ/mo)
MO.      LOAD   SOLAR DEMAND    FUEL
A        1.09   0.94   0.15    0.15
S        1.08   0.78   0.30    0.30
O        1.22   0.54   0.68    0.68
N        1.26   0.24   1.01    1.01
D        1.32   0.10   1.23    1.23
J        1.32   0.19   1.13    1.13
F        1.21   0.43   0.77    0.77
M        1.30   0.75   0.55    0.55
A        1.23   0.91   0.32    0.32
M        1.21   1.07   0.13    0.13
J        1.11   0.98   0.12    0.12
J        1.09   1.01   0.08    0.08
YR.     14.44   7.97   6.48    6.48

ANNUAL SOLAR FRACTION =      .55

ANNUAL FUEL COST =       $ 261.01
  (Fuel at $ 40.3 /GJ)
```

```
SYSTEM PARAMETERS                 VALUES
Collector: Area (m2)               6.06
  Loss Coeff. (W/Cm2)              3.2
  FR(Mean τα)                       .63
  Azimuth.Slope (deg.)           180.3
  Ht  exch. coeff.                 1.00
Demand exch. coeff.                 .86
Demand water temp. (C)            55
Water Supply temp. (C)            M4
Water Demand (L/day)             200
Aux. Seasonal eff.                 1.00
Fuel rate ($/GJ)                  40.3

 KITKATLA DHW
 3Col; 4Pers; Elec
```

```
KITKATLA DHW: 3 col /high load

 COST           $ 5200.00
 SAVINGS $/yr   321 19

 Interest         12.00
 Discount         10.00
 Inflation        12.00
 Finance          20 yrs

 YEAR  CUM. NPV ($)
  01        -341.
  02        -619.
  03        -839.
  04       -1007
  05       -1125.
  06       -1198.
  07       -1230
  08       -1224.
  09       -1182.
  10       -1107.
  11       -1001.
  12        -867.
  13        -706.
  14        -521.
  15        -311.
  16         -80.
  17         172.
  18         443.
  19         733.
  20        1041.
```

APPENDIX 6 - SMALL SCALE HYDRO-ELECTRIC SYSTEM CALCULATIONS

Billy Creek Drainage Area, Porcher Island
Area - 8.7 square miles; Potential Head - 200 feet

Annual Rainfall - based on Sandspit, approximates dry year
at Prince Rupert.

Prince Rupert	2403 mm	Streamflow @ 75% of rainfall
Prince Rupert Airport	2523 mm	System efficiency is 70% of potential energy
Sandspit Airport	1281 mm	

Month	J	F	M	A	MY	JN	JL	A	S	O	N	D	Year
Precipitation mm	144	113	100	84	52	52	43	50	90	194	181	178	1280
Streamflow q - cfs	32	28	22	19	11.6	11.9	9.6	11.1	21	43	42	40	24.2 cfs average
Power P - kW	379	328	263	228	136	141	113	131	244	509	491	468	285 kW average

Costs: Plant - 400 kW @ $3125 = $1,250,000
(includes civil, penstocks,
turbine, control, electrical)

Transmission - 7 km overland @ $30,000 = 210,000
- 3 km underwater @ $60,000 = 180,000

Total estimated cost = $1,650,000

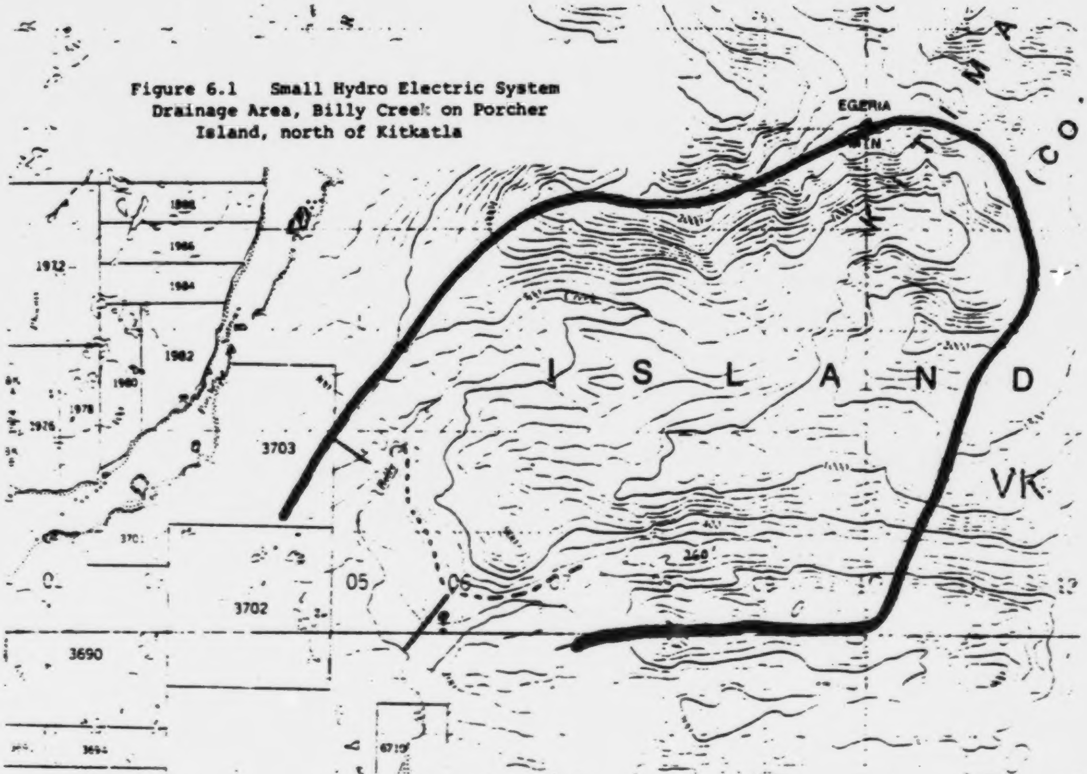


Figure 6.1 Small Hydro Electric System Drainage Area, Billy Creek on Porcher Island, north of Kitkatla

EGERIA
MTN
I S L A N D
VK
(CO.
1988
1986
1984
1932
1982
1980
1978
1976
3703
3701
3702
3690
05
06
360
6710
6709
3694
3693
3695
3700
3699
3698
Billy Bay
Gladstone Islands
Billy Is
K I T K A T L A
Pelham
Islands
Gibson Island
6711
6712
SANDY ISLAND
GRASSY ISLAND
SHAKES
137